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Historical Apparatus at the University of Mississippi

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THE study of physics and astronomy has been given considerable emphasis at this institution ever since its founding in 1848. Indeed, just prior to the Civil War the University of Mississippi possessed equipment in these fields equal, if not superior, to that of any institution in the United States. Such a statement might be open to question were it not for the fact that the greater portion of this equipment is still in existence in a serviceable condition. In view of these circumstances, it is believed that a short description of some of the more important pieces might be of interest to physicists elsewhere.

The first professor of natural philosophy at the university, John Millington[2] (Fig. 1), gave lectures before the members of the Royal Institution of Great Britain for fourteen years (1815–29). Upon his removal to the United States, he brought with him a number of pieces of apparatus which were later purchased by this institution. Among these might be mentioned a ten-cell section (Fig. 2) of the Royal Institution battery of 2000 cells with which Davy (Fig. 3) and Faraday performed their classic experiments. Several pieces of the apparatus are the result of Millington's own labor (Fig. 4).

With the advent of Professor F. A. P. Barnard (later of Columbia University) to the university in 1854, scientific study here received tremendous impetus. By 1857 orders had been placed for equipment second to none in this country. It is

FIG. 1. John Millington, M.D. (1779–1868), from a photograph given to this department by his daughter, Mrs. Kate Millington Blankenship.

[1] The article follows somewhat the plan of a paper presented by the senior author at the meeting of the Southeastern Section of the American Physical Society, Feb. 19, 20, 1937.

[2] For a detailed biography of this interesting individual, see S. C. Gladden, William and Mary College Quart. Hist. Mag. 13, 155–62 (1933).

BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS
LIBRARY

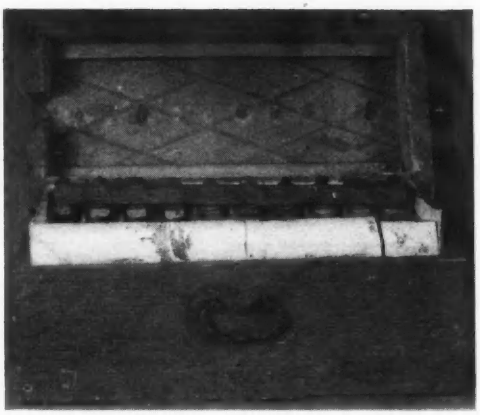

FIG. 2. A section of the Royal Institution battery. Apparently the familiar copper-sulfuric acid-zinc combination was employed.

"THE FIRST EXHIBITION OF THE ELECTRIC LIGHT—1810"

We give an illustration of no small historic interest. It represents the first exhibition of the electric light by Sir Humphry Davy, at the Royal Institution in London, in 1810, and we reproduce it from 'La Lumiere Electrique.' The date is so recent as to belong to our own times. The story of the display may be briefly told. As our readers know, Volta announced in 1800 the invention and construction of his pile, the first source of dynamic electricity. A year later, Davy, only twenty-one or twenty-two years of age was appointed assistant lecturer at the Royal Institution, and, entering upon his duties with zeal and ardor, he was not slow to avail himself of the means for investigation and experiment placed at his disposal there in the Voltaic pile. He made good use of the earlier batteries provided, but in 1808 found himself in possession of a battery of Brobdingnagian proportions, purchased by the subscriptions of a few generous patrons of science. It consisted of 2,000 cells, arranged in 200 porcelain troughs in a vault, after the manner indicated in the lower portion of our illustration.

Davy had discovered and shown the carbon light on a very small scale in 1802, having learned how to obtain an 'arc' by holding together two pieces of charcoal that were connected to the opposite poles of a battery and then drawing them apart; and he could now repeat his experiment on a grand scale and with startling brilliancy before the members of the Institution. It is well to give his own description of the display: 'When pieces of charcoal about an inch long and one-sixth of an inch in diameter were brought near each other (within the thirtieth or fortieth part of an inch) a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness; and, by withdrawing the points from each other a constant discharge took place through the heated air in a space equal to at least four inches, producing a most brilliant ascending arc of light, broad and conical in form in the middle.' The length of this arc was increased in vacuo to seven inches. The delight and surprise of the spectators was evidently very great.

—*Electrical World*, April 12, 1884.

FIG. 3. A reprint of interest dealing with the Royal Institution battery (by permission of the *Electrical World*).

believed that the leading instrument makers of France—Marloye, Lerebours et Secretan, and others—were given instructions to duplicate the apparatus described in Jamin's *Cours de Physique* (Paris, 1858), as a detailed study of that work and of the first inventory book of this department (dated 1861) indicates. Space does not permit but a cursory mention of this equipment. Suffice it to say that replicas of the apparatus designed by all of the leading scientists in the fields of physics and astronomy were represented.

A few items are worthy of detailed description. A unique portion of the collection is a set of 80 original oil paintings about two feet square from the Atelier Clichy, Paris, which represent all of the important cases of diffraction and polarization. Several of them are shown in Fig. 5 and in the background of Fig. 6. These paintings appear to have been the originals from which were made the beautiful color plates in *Les Phénoménes de la*

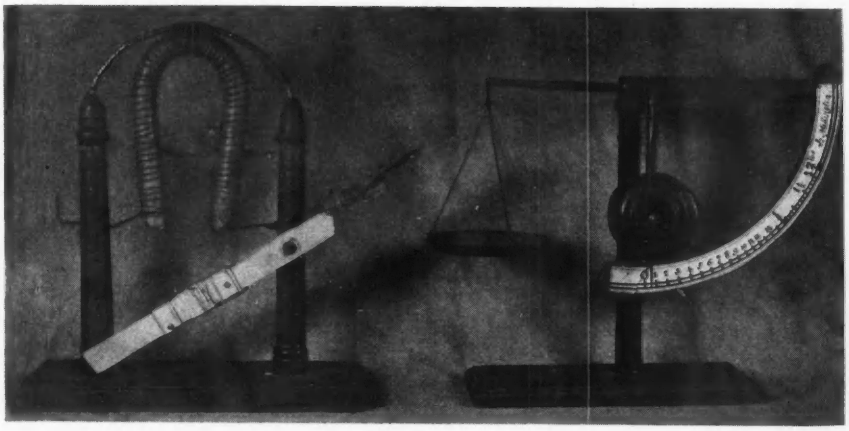

FIG. 4. Electromagnet (left) and balance (right) built by Dr. Millington about 1840.

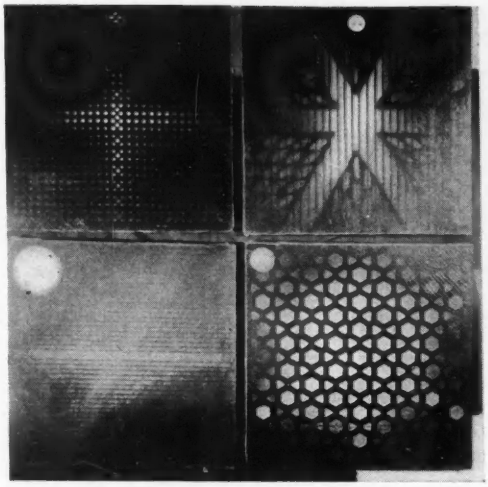

FIG. 5. Original oil paintings of optical phenomena. The small white circles at the top of the paintings indicate the particular arrangement of apertures employed. In the paintings shown, red light was portrayed, although other sources are represented in the collection.

Physique par Amédée Guillemin (Paris, 1869). Some of the single pieces of optical equipment are illustrated in Fig. 7. Another item is described in the first inventory book of this department as

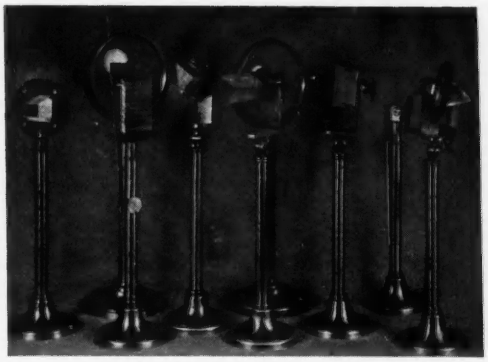

FIG. 7. Representative pieces of optical equipment.

Pouillet's "Grand Appareil pour les experiences de diffraction et d'interferences," containing every piece described in Pouillet's *Physique*, and illustrating all the phenomena of diffraction.

It is interesting to note that this optical bench still serves to produce quantitative as well as qualitative data for students at this institution. Other optical pieces include: Fresnel's compound burning lens, 2 ft. in diameter (Fig. 8); Silberman's heliostat; polarizing apparatus of the types designed by Arago, Norrenberg, and Biot; the camera lucida; the camera obscura; various

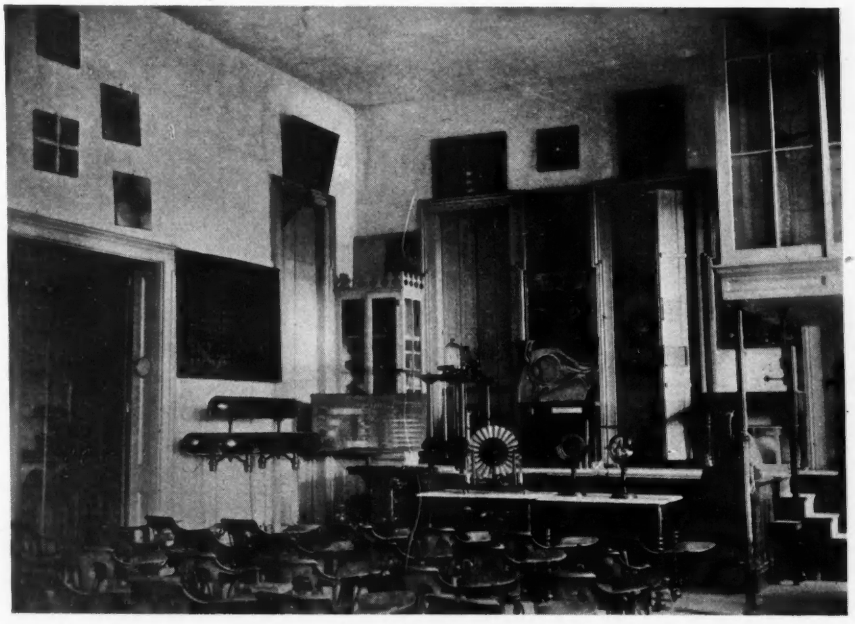

FIG. 6. An old photograph of the lecture room. The iron chairs were designed by Professor Barnard.

FIG. 8. Fresnel's compound burning lens, or solar furnace. Copper may be easily fused with it.

FIG. 9. An example of the simpler patterns of polarizing plates.

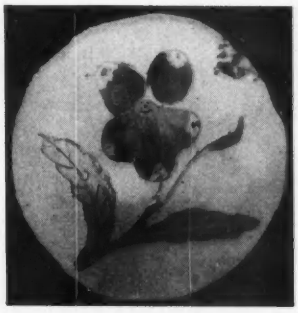

FIG. 10. Another design, in which a dozen different shades of color may be observed in the original.

types of projection apparatus with hand-colored slides; a Nicol prism 7 cm long and with a 3×3 cm face.

The apparatus for exhibiting the phenomena of polarization includes some two dozen mica plates cleaved to exhibit colored patterns when examined by polarized light. When it is stated that the patterns range from simple geometric figures to elaborate pictures of flowers, insects, people, and scenes, and that the colors are dependent upon the thickness of the mica, it is no less than amazing to note how excellent a gradation and variety of color is obtained. Two examples of these are illustrated in Figs. 9 and 10, although the delicacy of coloring is of course lost in the black-and-white reproduction.

No field of physics was slighted. In sound (Fig. 11), quoting from the catalog of the university for the ninth session (1856–57),

> . . . the apparatus of the University is complete; embracing every important instrument in the catalog of Marloye of Paris, whose name has so long been associated with this specialty, and who, since his retirement, has been replaced in this manufacture by Secretan, by whom the University has been supplied.

FIG. 11. Nodal apparatus. When the bowl is set into vibration, nodal points are located with the aid of pith-ball pendulums. The drinking glass gives an idea of its size.

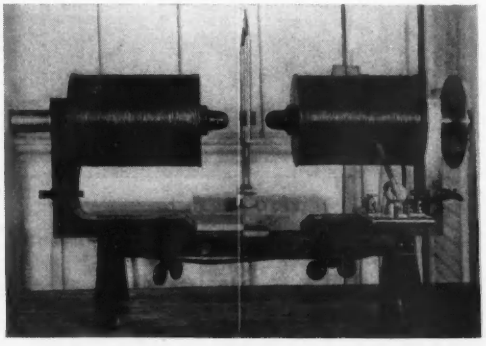

FIG. 12. Ruhmkorff's large electromagnet, with polarizing attachments.

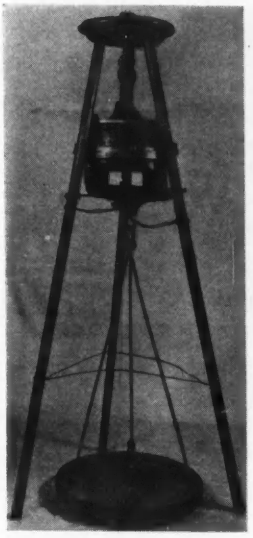

FIG. 13. A mounted piece of magnetite.

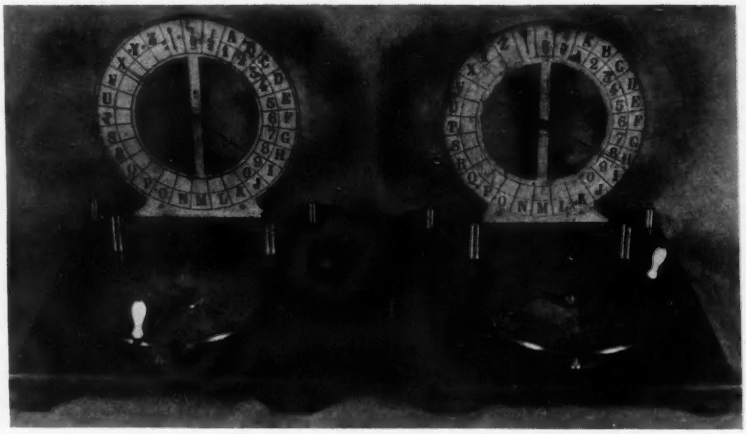

FIG. 14. An old-time type of telegraph transmitter and receiver.

The collection will, therefore, be found to contain all the ingenious contrivances of Savart, as, for example, his monochord, his large apparatus for illustrating the sympathetic vibration of a column of air with a bell, his toothed wheel and spring, his system of parallel bars, etc., with a great variety of tubes, embouchures, organ pipes, plates and membranes for producing acoustic figures, diapasons of various pitch from CC upward, Wheatstone's arrangements for interference, the siren of Cagniard for registering vibrations, etc., etc.

Mechanics was illustrated by means of working models of all the principal types of machines. The steam engine was represented by models,

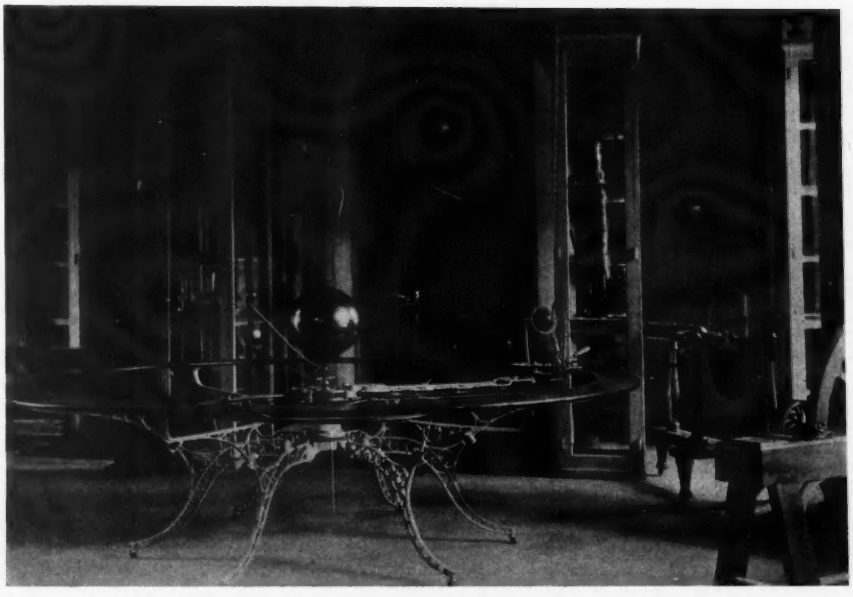

FIG. 15. A corner of the apparatus room, from an old photograph. In the foreground is the planetarium of Barlow; at the right, Savart's toothed wheel.

FIG. 16. Observatory and physics laboratory, University of Mississippi.

including the stationary, locomotive, and marine types. Dissected models of cardboard were also supplied to give the student a clear idea of the operation of the different parts. Two large air-pumps were ordered, one constructed by Ritchie (Boston), the other by Secretan (Paris). Various types of barometers are listed in the inventory book.

Of all the divisions of physics, heat was perhaps the one least represented, only one page of the inventory book listing apparatus of this nature, as compared to seven pages for optical equipment and sound, respectively.

In electricity, all of the important apparatus of the period is listed in the inventory book. Here might be mentioned the large magnet constructed by Ruhmkorff (Paris) to illustrate the diamagnetic effect (Fig. 12), and a specimen of magnetite (Fig. 13) originally capable of supporting a load of 100 lb. One of the largest electrostatic machines built at that time for this institution utilized two glass plates each 5.5 ft. in diameter. Unfortunately, because of ignorance concerning the electrical properties of different kinds of glass, the insulating pillars were made of poorly insulating material, with the result that the machine never produced discharges of any appreciable magnitude. This machine may be dimly seen in its glass-enclosed room in the upper right-hand corner of Fig. 6.

In astronomy, care was taken to insure that the equipment should be of the first rank. Barlow, of Lexington, Kentucky, was entrusted with the task of making a planetarium 11 ft. in diameter to illustrate the relative sizes and motions of the planets (Fig. 15). Two globes by Malby (London) each 36 in. in diameter—one terrestial, the other celestial—served to aid in the solution of astronomical problems. Additional

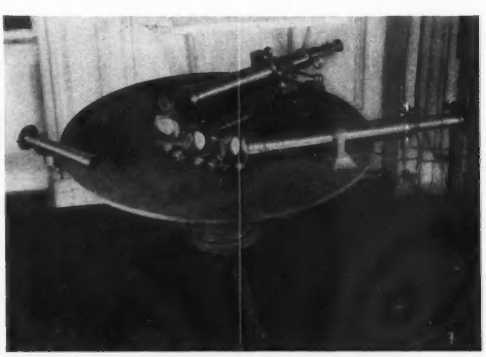

FIG. 17. Kirchhoff's table spectroscope.

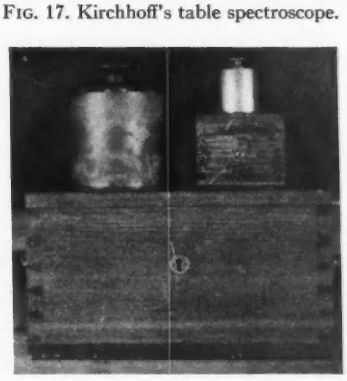

FIG. 18. Standard kilogram and ten-kilogram masses. Other masses are inside the case.

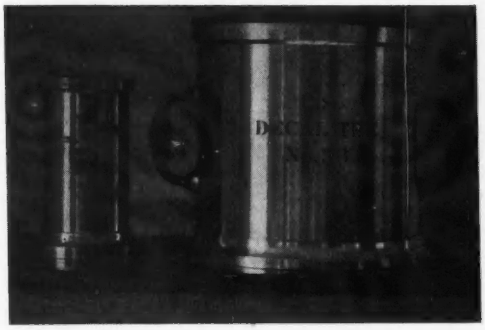

FIG. 19. Standard liter No. 38 and decaliter No. 38.

astronomical equipment included a meridian transit instrument, sextants, a comet seeker, and a 5-in. refracting telescope. It is perhaps not a matter of general information that the largest telescope in the world was contracted for by the University of Mississippi. Delivery of this instrument being prevented by the Civil War, it now serves Dearborn Observatory of Northwestern University. With this telescope the makers, Alvan Clark and Sons of Cambridge, Massachusetts, discovered on the first night of test the predicted companion of Sirius. The quarters of the department were originally designed as an observatory, as may be noted in Fig. 16.

Provision was also made for magnetic observations. A building constructed of nonmagnetic materials was erected near the observatory. Precision types of magnetometers and dip circles were supplied, together with other accessory apparatus. One of the three Ph.D. degrees ever conferred by the university for work done in residence was awarded to Paul Hill Saunders for

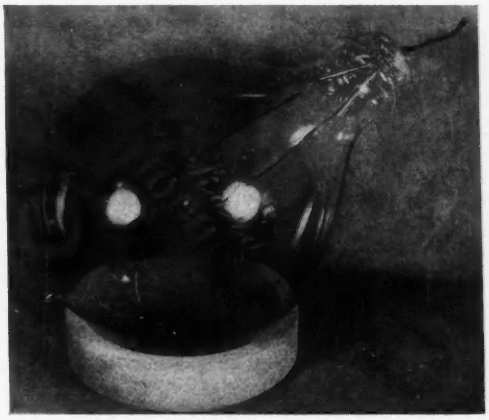

FIG. 20. An early form of electric light employing a carbonized bamboo filament.

determination of the latitude and magnetic elements of this station.

Following the Civil War, science was at a low ebb in the South. It was not until 1875 that additional purchases of equipment were made. In that year a Kirchhoff table spectroscope, with 4 prisms, was obtained (Fig. 17), as was also a complete set of Koenig's manometric flame apparatus. In 1878, set No. 38 of the United States metric standards (Figs. 18, 19) was delivered to the State of Mississippi in care of the university.

The presence of this high grade equipment at this early period is evidence that this institution was in reality a pioneer in the fostering of experimental science in America. Some years later a number of pieces of electrical equipment were obtained, of which a 1000-watt carbon lamp using a bamboo filament (Fig. 20) is a typical item.

John Dalton was not a fluent speaker, and when, as president of the Manchester Literary and Philosophical Society, he had to make a few remarks when the reader of a paper stopped, he is reported to have sometimes contented himself by saying, "This paper will no doubt be found interesting by those who take an interest in it."

J. J. THOMSON, *Recollections and Reflections.*

A Semi-Automatic Departmental Library

MARGARET C. SHIELDS
Princeton University Library, Princeton, New Jersey

THE departmental library is tacitly recognized by all physicists to be constantly the essential servant, and on occasions the guiding genius of all departmental activities. But it has probably never before been so bold as to make a public appearance on its own behalf in a periodical devoted solely to physics. Such an appearance is now attempted, at the instance of the editor, with the idea that suggestions as to how to achieve a more effective partnership between the library and the laboratory may be welcomed by some departments in which the responsibility for the library is wholly theirs, that is, when the collection must function without the exclusive attention of a trained librarian. Even the writer's library, indeed, falls practically in this category, since it is open twenty-four hours of every day of the week, and the librarian is on duty only a nominal working week.

The obvious first essential in every mind, an ideal fortunately rather generally attained, is that the books be immediately at hand, housed under the same roof with the department; otherwise, staff and student are tempted to make shift without the help they need. After this, the prime prerequisite for the convenient use of the collection is generally held to be a logical classificatory scheme by which the books are arranged on the shelves, the more urgent if undergraduates new to the literature of the subject are to help themselves from these shelves. Actually, any scheme will serve, once one has the swing of it, if only the classes are clearly defined and the scheme consistently administered, and no scheme is satisfactory if the meanings of classes are vague and differently interpreted from time to time.

Of the two standard schedules in use, both employ a terminology at points exasperating to physicists and bewilderingly different to a mere cataloger from that of the title pages of books. The Dewey system even in its latest revision reads like a table of contents of an old-fashioned textbook rather than a classification scheme of printed books. The Library of Congress system (hereafter called as in library parlance, L. C.) is generally passed over as much too elaborate for general use. As one instance of troublesome definitions, the L. C. class QC 701, defined as *Electric discharges*, is the only place provided for the large literature on thermionics; it might rightly be so defined, since with no books on disruptive discharge except such as go with *Dielectric properties*, and another number, designated as *Action of light, etc.* to take care of photoelectric emission, it becomes virtually a number for thermionics only.

The scheme shown in Table I is suggested as a possibility for a library just starting from the beginning or under the necessity of reorganization. At the left are Dewey numbers, their original definitions rather radically changed, though the outline still carries the general Dewey-like aspect. Dewey classes 531 and 532 have been combined (liquids and gases), 533–538 moved up one, and 539 expropriated to make place for modern physics. The order of subsections is also modified. At the right in Table I are the corresponding L. C. numbers, except that in some instances where no number sufficiently general was otherwise available, two or more major classes have been combined under one number. With minor classes thus pruned away the L. C. arrangement is seen to fit the needs of this simple program quite as well as the Dewey, except for placing *theoretical mechanics* in *mathematics* and twentieth century physics between *fluids* and *sound*. Obviously numbers between 0 and 800 could be assigned to put everything in the order of this outline within QC if it were so desired, or any other notation may be evolved to conform as it should to that maintaining elsewhere in the college system.

Whether they are housed centrally or with the department, it will be found a great convenience if all periodicals, even when they are devoted to some one section of the field, are shelved together in one class. In the departmental library this should include general sets like the *Proceedings of the Royal Society of London* and *Nature*, unless

there are many such, so that all periodicals stand as a unit in the simplest possible alphabetical arrangement. Dictionaries, sets of tables, and all strictly reference books for the departmental collection should be marked with a simple "*R*" and shelved regardless of their theoretical class number in the most convenient spot in the room.

When the departmental collection is separately housed and contains duplicates of books in other collections it is highly important that the books belonging to the physics collection should be classed for the convenience of that collection, whatever their number elsewhere. For example, analysis of musical sounds, acoustical problems of architecture, and books like Fletcher's *Speech and Hearing* should stand with sound, not scattered to music, architecture, and psychology, even though a second copy elsewhere with equal

TABLE I. *Classification schedule.*

530	Periodicals	QC	1
.1	Collected works and other miscellaneous collections		3
.2	Philosophy of science		6
.3	Biography and history, including history of special fields		7
.4	General texts, compendiums, encyclopedias		21
.8	Workshop technic, laboratory manuals		33
.9	Study and teaching		30
531	Mechanics, general	QA	805
.2	Statics and applications to theory of structures, etc.	QA	821
.3	Dynamics and kinematics	QA	845
.4	Gyroscopic motion and gyroscopes	QA	862
.5	Gravity determinations and gravitation	QB	331
.6	Ballistics	UF	820
.7	Simple harmonic and vibratory motion	QC	231
.8	Potential theory	QA	825
.9	Elasticity and strength of materials	QC	191
532	Fluid statics and dynamics	QC	145
.2	Wave motion	QA	927
.4	Aerodynamics, application to mechanical flight	QA	930
.6	Molecular forces in liquids: surface tension, etc.	QC	183
.7	Kinetic theory of matter, including osmosis, Brownian motion, etc.	QC	185
533	Sound, general	QC	225
.4	Architectural acoustics	NA	2800
.8	Musical instruments, analysis of musical sounds, speech, etc.	QC	246
534	Heat, general texts and laboratory manuals	QC	254
.1	Thermometry and the gas laws		271
.3	Calorimetry and change of state; liquefaction of gases		291
.5	Thermodynamics		311
.7	Transfer: conductivity and radiation		331
.9	Applications to steam engine, etc.	TJ	275
535	Optics, general texts and laboratory manuals	QC	355
.1	Special topics of geometrical optics; photometry, optical instruments, etc.		381
.2	Special topics of physical optics: diffraction, polarization, etc.		415
.4	Color; qualitative studies of radiation, luminescence, etc.		475
.5	Spectroscopy		451
.9	Photochemistry and photography	QD	601
536	Magnetism	QC	735
.5	Terrestrial	QC	815
537	Electricity, general texts	QC	518
.2	Electrostatics, properties of dielectrics		571
.3	Electromagnetism, electrodynamics, alternating current production and properties		641
.4	Electrical apparatus and measurements; standards and units		535
.6	Electron theory of metals; thermoelectricity, etc.		621
.7	Electrochemistry; voltaic cells, storage batteries, etc.		603
.8	Electromagnetic field theory, electric waves		670
538	Mathematical physics, general	QC	20
.3	Relativity		6
.5	Quantum theory, quantum and wave mechanics		174
.7	Statistical mechanics	QC	175
539	Atomic physics, general		173
.1	X-rays		481
.2	Radioactivity		721
.3	General electronics; discharge through gases, ionization, etc.		711
.4	Photoelectricity		715
.5	Thermionics and thermionic tubes		711
.6	Atomic structure: Bohr theory, etc.		173
.7	Nuclear structure: transmutation, induced radioactivity, mass spectra and isotopes		173
510	Mathematics	QA	36
521	Astronomy and astrophysics	QB	461
541	Chemistry	QD	31
548	Crystallography	QD	905
550.3	Geophysics	QC	806
551.5	Meteorology	QC	861
577	Biophysics	QH	505
621.37	Electric power engineering	TK	145
621.38	Communication engineering, including other applications of radio circuits.		
	(Telephone)	TK	6161
	(Radio)	TK	6550

logic requires the other classification. Likewise, supplementary books in cognate fields, the number of which will be small, are much better in a single class for each major field, regardless of the more detailed analysis required by the main collection in that field. It may not be easy to persuade the central library of this general principle, but its importance warrants a brave effort.

Beyond agreement as to an acceptable classification program, the successful library needs further help from the department in the work that must be done before the books appear on the shelves. It is doubtless the universal experience that to secure prompt appearance of new books up to the limit of the budget, some one member of the department must be charged with the primary responsibility of scanning advertisements and reviews in periodicals, the monthly book list in *Nature*, etc., and forwarding orders to the purchasing officer. But probably rarely is it recognized that since on the cataloging staff of very few libraries may one expect to find a person qualified to evaluate books in the field of physics, this process can be satisfactorily accomplished only with the oversight of some interested person. A cataloging department, grateful for having its number of puzzles reduced, will gladly notify a delegated person, perhaps the same person whose judgment is trusted for ordering, as books arrive. He may then call and place in each book a slip with instructions; for example, for John Thomson's recent book, *Introduction to Atomic Physics*, "Class. 539, subjects, *Quantum theory*, *Spectroscopy*." In nonambiguous cases such memorandums might even be forwarded with the order slips. In any case, the time consumed is small and it is recompensed by the assurance that purchases have been given their maximum availability.

Clearly, accurate and adequate subject entries in a catalog are an important supplement to the classification, in part because a distinct advantage lies with fairly comprehensive classes. How else shall a new explorer find the few books on band spectra from the many in the spectroscopy section, or those on television from among the radio books? How shall he find where the classifier has put the two unique books on molecular beams if he is so much a novice as to fail of knowing Fraser's name, unless there be a card under the fairly appropriate old entry *Molecular dynamics?* Or how shall he discover except by an entry under the subject that the treatment of relativity he is seeking is in a book by Jeans on the philosophy shelf? Even where there is a one-to-one correspondence between a class of books on the shelves and subject cards in the catalog these cards are still useful for calling attention to books off the shelves, and, if they are filed by date of publication, for answering the question as to what is the last word on a subject.

Further, at many points the L. C. published list of subject entries needs revision and addition, but the professional cataloger who is not a physicist feels herself bound to conform to it. It is not only the books on what Darrow has called "the renaissance" of the last half-dozen years for which inadequate provision is made. Twenty-eight years after Richardson made current the term thermionics, *Electric discharges* is still the nearest approach to it on the list. (This, by the way, is the entry under which the subject stood in *Science Abstracts* until in 1923 it adopted *Thermionics*.) In 1881 Sir Arthur Schuster, in an address before the Royal Institution, entitled "The Teachings of Modern Spectroscopy" pointed out that the time was long since passed when analysis was the chief concern in the study of spectra, and used freely without apology or explanation the term spectroscopy for the systematic investigation of spectra as pursued by physicists. The Oxford dictionary quotation under spectroscopy is from Sir William Huggins and dated 1870. But even yet the L. C. list recognizes only the term *Spectrum analysis*, which for half a century has stood in the mind of physicists only for one of the disciplines of chemistry. Interested and competent advice from a qualified physicist will almost certainly bring about the acceptance of some of the needed changes such as these in the cataloger's list, which, if not made, may justifiedly give rise to some loss of faith in the library as a whole.

Finally, it seems almost to go without saying that in case the books have the good fortune to be housed on the department premises, the catalog in that room should contain full cataloging: all subject entries, added entries for editor, series, etc.; all necessary references from not-used to

used forms; in short, all cards that may help in the identification of titles by partly informed searchers. If full cataloging can be provided in only one place, there is no doubt that it is much more needed with the books than in the main library. With it students may be often left to their own resources to great advantage, as they could not in fairness without it.

As to administering the use and circulation of the collection, so much depends on the number using it and on the sensitiveness of the social conscience of the group that the procedure in each case must be a matter of experience in that particular situation. At a minimum a card should be provided in each book to be signed and deposited when the book is taken from the room and replaced in its pocket when the book is returned, and some one member of the teaching staff should be recognized as in authority to see that the room is properly used, that the shelves are in order and that readers do not fail of getting with reasonable certainty what they want. Order on the shelves requires that the books be plainly and permanently marked with their numbers, so that rapid, frequent scanning of the shelves will catch misplacements which are inevitable on shelves really used by earnest students.

By no means are all these ideals fully attained in the writer's library, nor in other good libraries, since they involve an infinity of detail and many compromises with existing circumstances. They are, however, believed worth consideration from physicists who would make their libraries a vital part of their teaching and research equipment.

The Place of Graduate Work in the Preparation of Industrial Physicists [1]

WHEELER P. DAVEY
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SOME day, some one will write an interesting book, missionary in intent, telling of a few of the host of applications of physics to various industrial problems. His publisher will induce him to name the book *Industrial Physics*, whereupon a large number of departments of physics will immediately proceed to offer a course in industrial physics and will attempt to use the new book as a text. The sad awakening will occur when the staff discovers, too late to repair the damage, that the resulting course neither enables many of their students to get industrial positions, nor prepares the few who do get jobs to hold them successfully.

It is hardly necessary to say that industrial physics is not a separate branch of knowledge like trigonometry which can be taught in organized classes meeting a specified number of hours per week. Physics is still physics. It is still that science which deals with energy and with those properties of matter not intimately tied up with the determination of the composition of matter. Industrial physics is not some new kind of physics; rather, it is a serious attempt to apply all of the principles of physics to the solution of industrial problems. Accordingly, a "textbook" on industrial physics should not be a single book but should be a whole physics library; it should be a systematic series of books each dealing with a single phase of the subject. The complete series would cover the whole field of physics and the whole field of industry.

It is in the very nature of physics, as the most fundamental of the natural sciences, that it tends to deal in idealized abstractions and generalizations. But industry cannot manufacture and sell abstractions. It cannot wrap up a generalization in a package and sell it over a counter. Industry exists by dealing with *things*, and things are individual and concrete in their very nature. Obviously, a physicist can make himself useful to an industry only in so far as he is able to apply his generalizations and abstractions to specific things or to the processes necessary in the manufacture of specific things.

An industrial physicist must not only be a first class physicist; he must also be familiar with the fundamentals of a large number of other subjects so as to have a wide stock of concrete

[1] See also articles in *The American Physics Teacher* by H. L. Dodge, **4**, 167 (1936), A. R. Olpin, **5**, 14(1937), and J. A. Crowther (digest), **4**, 149(1936). Also see *Physics in Industry* (American Institute of Physics, 1937).

information to which he may apply his generalizations and abstractions. An industrial physicist not only must know as much physics as his non-industrial classmate, but he also must have an insatiable curiosity about every other science. Along with an intimate knowledge of physics and a good working knowledge of mathematics, he should have at least a speaking acquaintance with inorganic, organic and physical chemistry, colloids, metallurgy, and, if possible, biology and ceramics. These subjects will give him a picture of the sort of *things* with which industry has to deal, and a set of tools with which to study any one of them intensively *through the eyes of a physicist*, whenever he finds it necessary. Besides being in possession of this stock of information, an industrial physicist should have worked out an apprenticeship in independent laboratory investigation.

Such training cannot be obtained in four years of college work. It is all that the student can do to squeeze it into seven or eight years. In other words, the proper training of an industrial physicist requires at least three and usually four years of study after the B.S. degree. Experience shows that it is best for a student to get as much as possible of his work in the supporting subjects out of the way during his undergraduate period. Any first class liberal arts college, even though it be small, will enable a man to take four semesters of physics beyond elementary general college physics;[2] it will take him through partial differential equations, a year of French, two years of German, and three of English; and will give him stiff work in inorganic, analytical, and organic chemistry, and a really good two-semester course in physical chemistry. Many physics departments have a small shop in which the embryo industrial physicist can learn the proper use of shop tools and machines. If a student has done well in such an undergraduate training, if he has ambition, initiative, and a native curiosity, and if he is an "understander" as well as a "knower," he is usually ready to commence graduate work in physics.

The graduate work of a prospective industrial physicist should start with a general two-semester course in physics, given on the graduate level, and assuming the sort of undergraduate training already outlined. This will serve to put men from different types of colleges on a common level; it will provide them with a common starting point for further work.

Concurrently, the student should take courses in vector analysis and Fourier analysis, a basic two-semester graduate course in physical chemistry (say Noyes and Sherrill), and a two-semester course in crystal structure. The course in advanced physical chemistry will give the student a good physical picture of the nature of gases and liquids, and of the properties of solutions. The course in crystal structure will give him an equally valuable physical picture of the properties of crystalline solids. It should be followed by a two-semester course in colloids. In this way the student will have studied the properties of *things* used in industry from two standpoints; first, as an undergraduate, he learned to classify *things* as inorganic and organic *chemicals;* now, as a graduate student, he classifies them *physically* as gases, liquids, solutions, colloids, and crystalline solids. It remains to complete his study of *things* by a course in metallography, and, when possible, elementary course in biophysics (often given under the name "bio-colloids").

The study of physics should be continued by courses in mechanics, advanced laboratory optics, electron theory, vacuum tube circuits, two semesters of thermodynamics of the Lewis and Randall type, two semesters of statistical mechanics (for instance, Fowler), and, finally, atomic theory and quantum mechanics. To this must be added, of course, such other mathematics as may be needed, and an acceptable experimental thesis together with highly specialized study pertaining to the general topic of the thesis.

The topic of the embryo industrial physicist's thesis is not important as long as it is worth working on. It is not necessary for the research to be along lines that are of immediate industrial use. As long as his work yields a respectable contribution to human knowledge, the student may choose the most abstruse and "pure science" topic he can find, or he may take a topic in which there is some passing industrial interest. In either case, it is important that the student

[2] It is the writer's opinion that courses in "Modern Physics" should not be taken in undergraduate work. The time is better spent laying a good solid foundation. There is plenty of time for modern physics in graduate school.

should have worked out a thorough apprenticeship in semi-independent (i.e supervised) research and that he should have proved himself to have initiative and originality. In eleven years of training of graduate students the writer has yet to be asked by a prospective employer for a Ph.D. man whose thesis has been along some specified topic. Not a single one of the students who have taken substantially the training outlined in this paper has ever been put upon industrial work which was even remotely connected with his thesis topic. In every case, however, the prospective employer has had in mind a definite type of work which he wants the new employee to start on after being hired. Usually four questions are asked:

> Can he get along well with his fellows?
> Is he reliable and dependable?
> Have his studies included the topic on which he is to work at first?
> Can he teach himself the things he finds he needs to know in order to prosecute his work successfully?

Most employers expect that from time to time they will have to shift their main research attention from one topic to another as the needs of their industry change; hence the demand that industrial physicists have a large enough stock of mental tools covering a broad enough field so that they can train themselves for whatever line of work is assigned to them. The ability to study up *any* topic which may be of advantage to the employer is infinitely more important than a highly specialized training in some narrow field of immediate interest.

A student who has completed such a course of preparation should be in possession of the mental tools with which he can study by himself almost any topic which his job requires. Like his non-industrial classmate, he naturally must be willing to study two hours a night, five nights a week, forty-eight weeks a year. We cannot teach him in the university all that he will ever need to know. We have done our duty when we have provided him with the necessary tools for independent study—or at least the tools with which to acquire other more specialized tools when he needs them—and when we have given him a glimpse of the wealth of technical knowledge of industrial materials to which he must apply his physical viewpoint. We have given him ample insurance against the future and the future's new knowledge, for he will be able to keep himself up-to-date along any line of industrial and scientific activity which his job requires. If he becomes deadwood twenty years after he leaves the university, we can reasonably believe that it will not be our fault.

There remains the point that every industrial physicist, like every true scientist, must have proper disrespect for theories—his own included—and must regard them only as extremely useful pictures which are not necessarily true at all. He must learn to *use* theories, not *believe* them. He must take to heart W. R. Whitney's proverb, that "Nine-tenths of the literature, and one-tenth of every textbook is incorrect." He must learn to try experiments that are indicated by orthodox theory, and at the same time to try exactly the opposite type of experiment, and he must learn not to be too greatly upset to find that half the time the second type yields a useful result.

Some may be expected to ask, "How do you know your ideas on the training of industrial physicists are correct? Might not the opposite type of training turn out to be better?" My reply is that every Ph.D. from the Pennsylvania State College who has had substantially the type of training recommended in this paper has a job; most of them obtained their jobs during the depression; none has ever been discharged; many have had increases in pay and rank during the depression. Every man who went only as far as the M.S. degree, and who, as far as he went, followed substantially the type of training advocated in this paper, has a job. Every B.S. man who had the type of undergraduate training recommended, but who went no further, has a job. With two exceptions—an insurance agent and a secondary school teacher—all these B.S. men are in some sort of industrial technical work. For prospective teachers, too, the training recommended seems to work out well. Three Ph.D's with this training are now teaching in colleges and they have all been successful.

In terms of the end result, the writer stands on his recommendations.

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Edwin Herbert Hall

Recipient of the 1937 Award for Notable Contributions to the Teaching of Physics

Introductory Remarks by President F. K. Richtmyer. *Through the generosity of an anonymous donor the American Association of Physics Teachers is enabled to make annually an award of a medal, or some similar token, for notable contributions to the teaching of physics. I have pleasure in presenting Professor D. L. Webster, Junior Past President of the Association, who, as chairman of the Committee on Awards, will present the report of the Committee for 1937.*

Contributions of Edwin Herbert Hall to the Teaching of Physics

DAVID L. WEBSTER
Department of Physics, Stanford University, California

THE Committee on Awards for Notable Contributions to the Teaching of Physics recommends for the award of this year Emeritus Professor Edwin Herbert Hall, of Harvard University, in recognition of his pioneer work in the introduction of laboratory instruction in physics.

Professor Hall was born in Gorham, Maine, on November 7th, 1855. He attended Bowdoin College, where he received the degree of Bachelor of Arts in 1875, that is, at the age of nineteen, and that of Master of Arts in 1878. Continuing his graduate study at Johns Hopkins University, he received the degree of Doctor of Philosophy in 1880; and later, in recognition of his outstanding contributions to both teaching and research he was made a Doctor of Laws by Bowdoin College in 1905.

Among his contributions to research we naturally think first of the one that made his name a household word among physicists, namely, the discovery of the Hall effect; but perhaps an even better reason for thinking of him in this connection is his long series of researches after this discovery, on this effect and the three other effects analogous to it in the conduction of electricity and heat in magnetic fields; and we might well mention his numerous other experiments and his contributions to the theory of metal. Here, however, we are concerned with teaching.

While Professor Hall's innovations in the teaching of physics are now in use over the whole country, from his native state of Maine to California, Professor Hall's own teaching was all at Harvard. He went there as instructor in physics in 1881, became assistant professor in 1888, professor in 1895, and emeritus professor in 1921.

To those of us whose education in physics began within the present century it is indeed hard to believe what we read of the state of physics teaching before Professor Hall's work on it. Physics, to us, from our first contact with it, has always been an exact science. Objectively, physics tells us not only what sort of effects will occur when we operate a machine or an electrical device, but very exactly how great each effect will be. And subjectively, we not only get help from physics in thinking about

material things intuitively and qualitatively, but also we learn from physics how to think about them exactly, that is, both quantitatively and rigorously, or reliably. It is not presumptiveness on our part when we physicists talk about teaching students, with minds as good as ours, how to think. When we go before a class, and teach them how to apply the laws of statics, or Newton's laws of motion, or Maxwell's equations, we are not egotistically asserting our personal opinions. We are not even passing on the opinions of our authorities, however humbly or enthusiastically we may praise Archimedes and Newton and Maxwell. On the contrary, we are telling the students, "Here are certain laws, first formulated by these great men, and now illustrated by certain applications; but so that you will see exactly what these laws mean, we want you to go into the laboratory and actually see the laws at work as exact laws." And whenever the need for especially careful, rigorous thinking arises, and students find it incredible that they really should have to be so careful, it is not our beliefs that constitute the test of right and wrong; it is exact experiment—the laboratory.

To those of us who are pure-blooded twentieth-century physicists, the ideas just expressed are platitudes, and the omnipresence of laboratories seems like that of the air we breathe. But laboratories were not given us by inanimate nature alone; and when we read the textbooks of the nineteenth century we soon discover that they are really of recent date. More strictly speaking, the history of laboratories has many dates. But in the distribution of these dates the most notable concentration occurs in the last two decades of the nineteenth century. Before 1880, in fact, laboratory instruction was almost unheard-of. The experiments described in the textbooks in use then were often very good as far as they went, in a qualitative sort of way; they were good lecture material, but they gave no real idea of physics as an exact science. And the physics teachers of that day, especially in the secondary schools, were usually unprepared for a quantitative view of it, if indeed prepared for physics teaching at all.

And then came Professor Hall. With the conscientious thoroughness that characterized all his work, he thought out what sorts of experiments could be done by secondary school students, and what sorts of apparatus for these experiments could be bought or built on school budgets. Both for the students and the budget makers, Professor Hall was a pioneer. He had none of our twentieth-century laboratory lists and traditions to guide him. On the contrary, while the list he wrote was original, most of the twentieth-century lists read very much like it. Indeed, Professor Hall's list strikes a twentieth-century student much as Hamlet's soliloquy is said to have struck him, as containing too many hackneyed quotations; and for the same reason.

This list was published in 1886, under the title of the *Harvard Descriptive List of Elementary Physical Experiments*. In this long title the word "descriptive" was especially important, because every experiment was described by Professor Hall so well that even the ill-prepared and meagerly budgeted teachers of that day could take the Descriptive List and put it into action. And so, with good experiments and good descriptions of them, Professor Hall's work remoulded the entire scheme of secondary school physics.

First, this combination of qualities made it possible to incorporate the Descriptive List into the entrance requirements for Harvard College, and thereby to bring it forcibly to the attention of teachers in schools influenced by Harvard. But it soon spread far beyond the Harvard sphere of influence, to that of the National Educational Association. Within a decade or two the leading manufacturers of apparatus were turning out complete sets of equipment for the experiments on the Descriptive List, which they had renamed the *National Physics Course*.

Professor Hall, meanwhile, had gone on to further work for physics teaching. The book entitled *A Textbook of Physics*, by Hall and Bergen, in 1891, and another entitled *Laboratory Manual of Physics*, by Hall alone, in 1904, were among his further contributions. It is to these books that many of us here owe our first introductions to the science we have liked so well as to choose it for our life work. And of less direct influence on us, but more direct on our teachers, was another book, entitled, *The Teaching of Chemistry and Physics*, written in 1902 by Smith and Hall.

Professor Hall's influence on physics teaching, however, was not entirely through the Harvard Descriptive List and these other books. The same conscientious thoroughness that enabled him to acquire the material for these books and to present it so well was also a great inspiration to those who worked with him. And with these qualities I may mention others equally important. In fact from my own experience as a student at Harvard I could testify at length to his inspiring qualities; but some of the men who worked more directly with him can express these qualities much more vividly. In the words of one of his former teaching assistants, he was especially distinguished for "his downright intellectual integrity and his persistent efforts to make us think straight in regard to physical phenomena." Another of them speaks especially of his "great foresight and good judgment" and his "well-thought-out pedagogic philosophy." Still another emphasizes Professor Hall's qualities "as a man of wide human interests, deep convictions and unquestioned courage," and this assistant notes that Professor Hall's influence on prospective physicists, in this country at least, "laid a firm basis for the present experimental methods in physics, without which much of our interest and success in research would be impossible." Still another of his assistants sums up Professor Hall's strict intellectual honesty in the words, "His constant endeavor was to make difficult things understood, but by the interested effort of the students, nor would he try to make the matter look simple by slurring over the hard places." The possible severity suggested by this statement was tempered, however, "by his willingness to discuss difficulties privately, when his kindness and wisdom produced marked results."

This assistant did his Ph.D. thesis with Professor Hall as well as teaching with him, and so was in an especially favorable position to speak of him, so I take the liberty of quoting further, as follows:

> Since the educational task is more than the mere training of intellect, the effect of the whole personality of an educator is of vital importance to junior students and thus to teachers of these. It may be of some value to you to have set down what seemed to me to be those elements of character which he possessed, and of whose presence one was always conscious, no matter upon what work he was engaged. His unremitting industry, his devotion to scientific progress and to his students, junior and senior alike, his intellectual honesty, his courage in the face of personal and professional difficulty, his fairness to others, his loyalty to those in whom he believed, his sensing of tough spots for the other fellow, and his stimulating expression of confidence at such time—all of these qualities combined to leave upon those who were near enough to sense them an influence that endures through life.

Mr. President, all these considerations, both professional and personal, make it the greatest of pleasure to report a unanimous recommendation for Professor Hall by the Committee on Awards for Notable Contributions to the Teaching of Physics.

Presentation of Award by President Richtmyer

No words of mine could add to what Professor Webster has so well said. Although this award is made through the instrumentality of the American Association of Physics Teachers, yet I am sure that I speak for a much wider circle, not only of Professor Hall's fellow physicists throughout this country and abroad, but of generation after generation of college students who have studied physics under him, when I say that we all extend greetings to him on this occasion and express our enthusiastic approbation of the award.

Professor Hall, it is my great privilege, on behalf of the American Association of Physics Teachers, to hand you this certificate of award as a token of our esteem, of our indebtedness to you for laying so much of the foundations of our profession, and of the inspiration which you have been and will long continue to be to the great company of physicists throughout the world. The medal, which unfortunately is not ready at the moment, will be placed in your hands later.

I am further very happy to announce that you have been elected to honorary membership in the American Association of Physics Teachers —the first Honorary Member in the history of the Association.

Physics Teaching at Harvard Fifty Years Ago

EDWIN H. HALL
Emeritus Professor of Physics, Harvard University, Cambridge, Massachusetts

THE letter of Professor Webster informing me that a committee of which he is chairman had taken action proposing the award which has just been made caused me varied emotions. I was utterly surprised. I was pleased also, of course, for one is never too old to appreciate a compliment, and I regarded this as a very great compliment, a great honor, for which I now thank everyone who has had any part in conferring it. But I could not help having an uneasy feeling that there was some mistake about it, and if I had presently received a second letter or a telegram explaining that someone had blundered and asking me to forget all about the matter, I should have felt less surprised, and less pleased, than I was by the first letter.

It is true that, beginning a little more than half a century ago and continuing for many years, I did a lot of work, which proved to be effective, in planning and promoting a course of laboratory exercises in physics for use in secondary schools, especially schools preparing youths to enter college. The success of this work, for, whatever its defects or misdirections, it did have a wide and lasting influence, has always been to me a source of quiet satisfaction; but the thought had never entered my head that some day a body like the American Association of Physics Teachers might give me formal and public commendation for doing it.

The job was not a glamorous one, nor was it entirely of my own choosing. Rather it was assigned to me by circumstances of a rather compelling character. When I began teaching at Harvard in the fall of 1881 there was a physics requirement for admission to the college, but it was purely a textbook requirement and it was treated in a rather perfunctory way both by the preparatory schools and by the college. Many of the school teachers of physics were interested in the subject and desirous of doing good work, but the school equipment of apparatus was in most cases meager and few, if any, of the teachers had any training, except as they had trained themselves, in the performance of experiments in physics. The colleges of their day, and of my day, did not afford such training. For example, I had gone through Bowdoin College taking what physics was offered there, and I had never in college gone so far in the way of physical measurement as to determine a specific gravity or the focal length of a lens.

How the requirement was dealt with on the college side may be inferred from the fact that the man who immediately preceded me in reading the admission papers told me that he made up his mind to get up a speed of thirty an hour or "bust." As he lived to tell the tale, I suppose that he reached that rather inglorious aim.

For years I set and read every admission paper on the textbook requirement in physics at Harvard without having, so far as I can now remember, any consultation with other members of the department regarding the matter, with one exception. I once suggested to the oldest member of the department that we should drop Rolfe and Gillette's *Physics* from our list of approved textbooks. (The Rolfe of this reference was, by the way, the same man who was better known as a Shakespearean commentator.) When I made this suggestion the older man asked, "Why do you want to drop it?" I said "Because it is not up to the times." "That's just why I want to keep it," he answered. "Bringing it up to the times means putting in a lot of improper matter." (I am somewhat shocked to see how much like his attitude my own now is regarding some of the modern developments of physics.)

Two chemists, Professor J. P. Cooke, who was, I believe, the first man in America to have a laboratory for teaching chemistry, and President Eliot, who had worked in that laboratory, started the movement for laboratory work in the science requirements for admission to Harvard College. Members of the physics department, including myself, were asked to make up a course of forty exercises in physics suitable for school use. I felt that this could not be successfully done in a hurry, but two of my colleagues

undertook the task and got out speedily a program which was little more than a list of titles of exercises with references to various books for additional information. This effort failed and I was then asked to take the matter in hand. I did so and gave it most serious attention, but I could not dispose of it in a few days or even a few weeks, and presently signs of impatience appeared in high places. My position at Harvard was none too secure at that time and I saw that a crisis in my own affairs had arrived. One Saturday evening I went to talk the matter over with my good friend and wise counselor Professor B. O. Peirce, who lived some three or four miles away. Toward midnight I started for my home on foot. My wind was good in those days and I ran a good part of the way. With doses of strong coffee and perhaps occasional snatches of sleep I worked through the night and through the next day. On Monday morning I had directions for thirteen of the proposed forty exercises written out in minute detail, and I took my manuscript to President Eliot. He examined it as he ate his lunch and approved it, all except one exercise which, from his own experience, he rejected as too wasteful of material. I think he liked my project none the less because of the fact that he could change it in this particular. He was a good listener and his mind was always open to well-considered propositions, but he liked to improve upon, and he usually could improve upon, such propositions. In any case I had gained his confidence. From that time on he gave me his powerful support and he took great pleasure in seeing the influence of Harvard spread throughout the country in what he believed to be a beneficent educational movement.

As I have spoken of President Eliot and my relations with him, I shall interpolate here the story of a little incident that occurred in New York City at the end of a meeting in which I had been carrying the new gospel to a body of physics teachers. An impressive-looking individual, stout, carrying a cane and wearing spats, announced himself to me as the head of a certain clipping bureau and suggested that I put my name on his list of clients. I was properly flattered, of course, but modestly said that it would hardly be worth while for his office to bother with me, as I was mentioned so seldom in the public news. Now these words of mine were true as well as modest and we know that the truth is mighty and must prevail, but I was not prepared to have it prevail so completely and so suddenly as it did in this case. The man made no argument whatever. He merely said, "Well, I'll admit we shouldn't make fifty cents a year on you, but here, take this card and give it to President Eliot. See if you can't interest him."

When I turn from this particular field of my educational activity and survey in retrospect my performance on the intellectually higher planes of professional effort, I find little enough ground for self-complacency. The fact that I held a Harvard professorship of physics for many years and retired from it voluntarily at the age of sixty-five may be taken, I suppose, as evidence that I met in some fashion the requirements of the position. But when I say this I recall a remark made by a former Harvard associate who was a German. One evening he had put on formal dress and was looking dubiously at the waistcoat when this colloquy occurred between us, he being the first to speak:

"Vest radder short."
"Well, it meets the trousers."
"Yah, it meets; meets kinder scarce, dough."

Perhaps especially since my retirement sixteen years ago, as I have witnessed the smoothness and efficiency with which my younger colleagues carry on the work over which I used to stumble and bungle, I have recalled with sympathy a remark of William James about himself, "All I know about pedagogies is that I am a darned poor teacher." I like to believe that some of my former students remember me kindly, but I am only too sure that, if search were made, others could be found who would say little in my favor, though I doubt whether any of them would express their disparagement so deftly as one did speaking to me directly many years ago. This fellow was, or so I had taken him to be, both dull and lazy, and one day I took him to task for his remissness in my course. But he turned on me with this entirely unexpected defense, "Well, Professor, I can't afford to neglect my education for this course."

But perhaps I have now said enough in the way of self-depreciation. I must remember that some of those here present have committed themselves to the proposition that I have contributed something of value to the art of teaching physics and though I may suspect that you have done so under some measure of illusion, yet, since I, knowing your commitment, have come here as your guest, common civility should prevent my dissipating that illusion altogether. So, instead of merely making the confession that I was a poor teacher and leaving the matter there, I will put beside this confession a certain boast. I profess to have been an honest teacher, and "poor but honest" is proverbially the description of a certain worthy kind of person. Hamlet says, indeed, "To be honest, as this world goes, is to be one man picked out of ten thousand." But I do not claim so much for myself as that, not, at least, when I am talking to physicists. Hamlet was talking to a politician when he made that observation.

I mean when I speak of being honest as a teacher that I had, I believe that I had, a good grip, as a rule, on the fundamentals of what I was trying to teach and that I strove earnestly to give such a grip to my students. Sometimes I succeeded. The late Professor A. G. Webster, who was in the first class I ever met at Harvard and was one of the most brilliant students I ever had, said to me long after his graduation, "You were a pretty good teacher; you were a green hand but you taught me the meaning of momentum and energy." Now that was something worth while, for at that time intelligent people were still talking about the "conservation of force," with all the mental confusion that phrase would indicate. I am glad to remember that I rendered this service to such a man. If I could believe that I had done as much for all my pupils I should be more content. But there's the rub. When the conscientious and hard-working professor measures the gap between what he is able to do and what he thinks a really competent man in his position would do, the seeming serenity of his occupation is shot through with streaks of melancholy and at certain seasons, the examination periods for example, this melancholy may deepen into gloom.

What I am leading up to by these rather somber reflections is the fact that I once put into the form of a sonnet my feelings regarding the mid-year examinations. As many of you must have had emotions not unlike mine at certain dismal periods of the year and as a sonnet is by law only fourteen lines long, I shall venture to recite this one to you. But I should, perhaps, make one or two explanations in advance. At Harvard the little books in which students write their examinations have blue covers and are called "blue-books." Another item is, these verses were written so long ago that the "study-lamp" mentioned therein is the kerosene "student-lamp," which only the older ones among you will remember. Furthermore, the sonnet telling how I felt about mid-years was preceded by other verses telling how, at that time, I felt about sonnets in general as a form of literary composition. These prefatory verses are more than fourteen, but they are not interminable and, as they are relatively cheerful in tone, I shall recite them also, for they may lessen the gloom which the sonnet alone might cause. Here I go:

I've had a most curious feeling of late,
A bothersome bee has got into my pate
And he buzzes away in a fashion so queer,
Though I'd gladly be deaf, I cannot but hear.

This feeling is that I've got to write verse;
I've had that before but I've got it now worse,
For never till now have I known to a "t"
Just the number of lines in my poem-to-be
And the length and the style of those lines, without
The slightest idea what they were about.

But I'm taking, as theologues take homiletics
A laboratory course in poetics,
And I'm bound to find out, if I can, what the D—!
The sensation of writing a sonnet may be.

So I've read the poets known to fame,
From Shakespeare down to what's his name,
The great and the small, the good and the bad,
Who this peculiar complaint have had,
And I've courted the mood in which they wrought
Till my wooing at last success has brought.

For now, with a hickory-dickory-dock,
My brain begins like an ancient clock
Which, slow and heavy and lacking oil
And striking the hours with evident toil,
Yet, wound for a certain time to run,

Must go till its solemn task is done.
And this, or I misread them quite,
Is the way of those who sonnets write.

But hark, the clock grows vocal now
And forms those words, I know not how:

Sonnet

Mid-years! When I behold the column tall
Of booklets blue thou rear'st upon my floor,
Then blueness like an ocean floods me o'er
And deep as this pile's height my soul doth thrall.
And when on my vexed eye it soon doth fall
Book after book repeateth o'er and o'er
That two times two is—anything but four,
On each dull page a zero large I scrawl.
Thus far proceeds my rising wrath, but when
Book after book declares it taught by me
That two times two is either five or three,
I turn me back and mark each question ten!
Then while my study-lamp yet bravely burns
The blue that wraps my soul to blackness turns.

I came to think better of sonnets in my later years, but not of mid-year examinations.

Now I have said enough about myself. I wish to speak briefly of teaching, as a profession, especially the profession of teaching physics.

Charles W. Eliot as a young man had an attractive invitation to go into business, the then flourishing industrial business of New England, but he declined it. He chose rather to enter the field of education, because he believed that by so doing he could best promote the welfare of the nation, could most vitally influence the character and the conduct of the American people. He was sometimes criticized as lacking idealism, as being utilitarian and materialistic, because he did not have that mystic faith in the special value of the study of Greek and Latin which was prevalent in New England seventy years ago. Well, he was utilitarian in this sense that he put foremost in his purposes of education the attainment of usefulness, and for this reason, that only the man who can be useful to society can have the fundamental virtue of self-respect on which stand so many of the other virtues. His conception of usefulness was not limited to material conditions but it heartily included material conditions, and his conception of a liberal education heartily included the physical, the mental and the moral discipline of direct, observant contact with material things.

The great merit of physics as a discipline is that it teaches veracity. William James once said to me that physicists—I have no doubt he included chemists in his thought—had taught the world the meaning of truth. Men can debate forever and inconclusively questions of philosophy or economics or forms of government, because you cannot take these questions into a laboratory and settle them in a few days or few years by objective evidence. But the laws of physics are so direct in their application and so inevitable in their consequences that nobody undertakes to trifle with them. It is good for us to know that there are certain established principles which no subtlety of argument can evade and no human eloquence can weaken. They will do their work, for our good if we learn to use them, for our harm if we try to ignore them.

It is the great advantage, the great happiness, of the physical science teacher that what the whole world requires of him is simply this, to learn and to proclaim the truth, without distortion and without reservation. What a soul-satisfying condition of life and work that is!

Rowland of Johns Hopkins once met one of his former students and asked him whether he was doing any original work. "No," was the reply, "I haven't any time or any money." Rowland shook his head; "Don't need any time, don't need any money, if you've got the will."—E. H. HALL.

Philately for Physicists

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EVERY ardent philatelist experiences quite a thrill when he captures some long elusive, rare, postal issue. If the philatelist is also a physicist, his thrill will be even greater and more lasting if the new acquisition has some bearing on physics. The designs on various postage stamps can be made the basis for the development of a fairly inclusive outline of physics and its progress through the centuries. The following paragraphs are intended to demonstrate some of the possibilities.

The philatelic physicist is fortunate in that he can begin his series with an Egyptian stamp bearing a likeness of Imhotep, said to be the first man of whom we have any important authentic record. This Egyptian physician and architect[1] (Fig. 1), who lived 48 centuries ago, is mentioned here because he designed the first pyramid and supervised its construction. For ages the rulers of Egypt had built their tombs of sun dried brick, these table-like structures being known as "mastabas." Through the services of Imhotep, King Zoser had a much larger mastaba built of stone. Later, receding stages were added, the final result being Zoser's step pyramid, 195 ft. in height. Imhotep must have been well schooled in practical mechanics in order to rear a structure of enormous pieces of rock, each many tons in weight, in a land where such material had to be imported. This Egyptian may therefore be remembered as the first engineer of whom we have specific knowledge.

Skipping across the centuries—twenty-five of them—we come to the comparatively new civilization of Greece. To Hellas goes credit for "the first instance of the definite formulation of a law of physics;" the principle of Archimedes (Fig. 2) is the only principle coming from antiquity (3 B.C.) in the precise form in which it is included in many physics texts of today. While the screw was known in Egypt three centuries before the Christian era, it was Archimedes who found new applications for it; an important modern application is shown in Fig. 3.

Although referred to as "the last great figure of the Middle Ages" our next character may be thought of as forming a liaison between the twilight of the Middle Ages and the dawning of the modern era. Leonardo da Vinci (Fig. 4), the author of a book on mechanics, attempted to build a heavier-than-air flying machine, based on numerous observations of various kinds of birds in flight. Leonardo was also the first to devise a self-indicating balance.

The period ushered in by another illustrious Italian is frequently referred to as the "beginning of true scientific development." Galileo Galilei (Fig. 5) was the first great protagonist of the scientific method and the founder of the science of dynamics.

No scientist would put complete faith in statements on the printed page, even when ascribed to certain authorities. In the same manner the philatelist will find it advisable in some instances to check on the plausibility of designs found on various postal issues. A stamp which portrays Columbus sighting land with a telescope (Fig. 6) would detract from the credit due elsewhere. Actually, telescopes were not known in the fifteenth century. It was in 1608 that the Dutch optician, Lippershey, discovered the principle of the refracting telescope while working with spectacle lenses. Less than six months after he had applied for a patent, a description of the device reached Galileo in Italy. As soon as the latter was able to construct a telescope he employed it in observing the heavenly bodies

FIG. 1. Imhotep [Egypt 144].

[1] In the text and in the legends of the figures the name followed by a number denotes the country by which the stamp was issued and the number assigned to the stamp in *Scott's Standard Postage Stamp Catalogue*. Where such catalog numbers have been omitted the issues have appeared too recently to be included in the 1936 catalog.

FIG. 2. Archimedes' principle [Falkland Islands 66].

FIG. 3. An issue [Russia 530] in commemoration of the 350th anniversary of Ivan Fedoroff, who introduced the printing press into Russia.

FIG. 4. Leonardo [Italy 1028].

FIG. 5. Galileo [Italy 1716].

and, as a result, became converted to the Copernican heliocentric theory [Portrait of Copernicus, Poland 192]. Early attempts to build better telescopes brought considerable disappointment to astronomers and physicists; it appeared impossible to prevent chromatic and spherical aberration in the more powerful instruments. The first practical solution to the problem was offered by René Descartes (Fig. 7); his suggestion to employ lenses of longer focal length eventually made better instruments possible, but also resulted in the unwieldy monsters known as "aerial telescopes," some of which were 200 ft. in length.

Queen Elizabeth's portrait on a stamp [Newfoundland 224] may be mentioned because under her patronage the chief court physician, William Gilbert, inaugurated the scientific study of magnetism. A number of his experiments were performed before the Queen. One may add a word concerning magnetic declination. It is generally stated that this phenomenon was discovered by Columbus,[2] whose sailors thought the compass was bewitched, but lines which have been construed to represent this declination appeared on charts published by an Italian, Bianco, as early as 1436.

Although "frictional" electricity had been known for many centuries, it remained for Otto von Guericke (Fig. 8) of Magdeburg to construct the first static machine. Better known are his invention of the air pump and the spectacular demonstrations with the famous Magdeburg hemispheres. When von Guericke's experiments with the air pump became known Robert Boyle became extremely interested. Concerning the originator of Boyle's law it has been claimed that his merit as a scientific investigator was that "he carried out the principles which Bacon [Newfoundland 92] preached in the *Novum Organum*. Yet he would not avow himself a follower of Bacon or any other teacher." Bacon's writings served as an impetus to the founding of the Royal Society.

Another heroic figure among scientists of the seventeenth century was the Dutch physicist, Christian Huygens (Fig. 9). Ranking next to Galileo and Newton, he was responsible for great advances in theoretical mechanics and physical optics. Of immediate practical importance to the world at large was Huygens' deduction of the laws of the pendulum. His introduction of the latter as a means for regulating contemporary clock mechanisms made more accurate timepieces possible.

Since physics relies so much upon mathematics, our collection should by all means include a stamp representing the calculus. Gottfried Wilhelm Leibnitz (Fig. 10), independently of Newton, evolved a method whose system of notation rendered it more flexible and simpler to apply.

For a good example of the practical application of the gas laws we may turn to the hot air balloon, invented by the Montgolfier brothers. Apparently the young Frenchman, Jean Francois Pilatre de Rozier (Fig. 11), was the world's first "air-minded" person. By making several ascents in a captive balloon during the fall of 1783 he demonstrated the fact that a balloon could carry human beings aloft. De Rozier likewise demonstrated that it was possible to carry fuel and thereby prolong the cruising time. On November 21st of that year this first aeronaut, accompanied by the Marquis d'Arlandes, ascended in the first free balloon to carry human passengers.

Improvement in modes of transportation by land and by water came after the development of appropriate sources of power. The first steam boat to engage in regular transportation in this country was the "Clermont" of Robert Fulton, a native of Pennsylvania. Although Fulton began

[2] Representations of Columbus, either full length or bust, appear on numerous stamps issued in the western hemisphere. Very good ones are Honduras 304, and Spain 741 and 745. A few others are Peru 178, Panama 802, and Salvador 157.

FIG. 6. Columbus sights land with an "undiscovered telescope" [St. Kitts-Nevis 1].

(a)

(b)

FIG. 7. Descartes. One of these stamps contains an error; the other is a corrected reissue.

FIG. 8. von Guericke.

FIG. 9. Huygens [Netherlands 488].

FIG. 10. Leibnitz [Germany 358].

FIG. 11. de Rozier.

FIG. 12. The Royal William [Canada 204].

as a jeweler's apprentice, he decided to make painting his profession. While visiting England he became acquainted with James Watt, and eventually inclined toward engineering. The Clermont [U. S. 372] was not the first steamboat; but she was the first *successful* steamboat in the United States. The first vessel to cross the Atlantic by employing steam power for the entire voyage was the Royal William (Fig. 12) in 1833; she carried practically

FIG. 13. An early "iron horse" and one of its modern descendants, commemorating a century of steam locomotives in Germany.

no cargo, as most of the space was required to store fuel. An important improvement in steam navigation was the invention of the screw propellor, patented by John Ericsson in 1836. [U. S. 628 represents his statue.]

Concurrently with the development of the early steamboat the steam locomotive was experiencing similar progress. It was in 1803 that the Cornish mine boss, Richard Trevithick, made the first successful demonstration of heavy haulage with a steam propelled vehicle over a prepared track. The first locomotive built to meet certain specifications regarding cost, size and performance was probably the "Rocket." In 1829, together with four other locomotives, it competed for a prize offered by the Stocton and Darlington Railway Company and, after a five day trial, was the only "iron horse" to meet the company's requirements. While, unfortunately, the Rocket has not been honored by any postal issue, early locomotives of several other countries do appear on stamps (Fig. 13).

Inseparably connected with the discovery of current electricity, near the beginning of the nineteenth century, are the names of Luigi Galvani (Fig. 14) and Alessandro Volta (Fig. 15). Among the pioneers in electrical experimentation we must not forget our own inimitable Benjamin Franklin [U. S. 552].

While it is true that the fundamental relationship between electric currents and magnetic fields was discovered by Oersted, it remained for André Marie Ampère (Fig. 16) to perfect our knowledge thereof and to formulate the famous "right-hand rule" and quantitative laws. This French physicist, who was also interested in botany, mathematics and poetry, was the first to distinguish between electrostatics and electrodynamics. The present use of the term "galvanometer" was likewise due to Ampère. The introduction of "ring winding" by Antonio Pacinotti (Fig. 17) paved the way for the modern dynamo.

FIG. 14. Galvani [Italy 329].

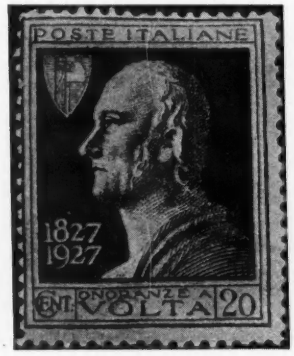

FIG. 15. Volta [Italy 188].

FIG. 16. Ampère.

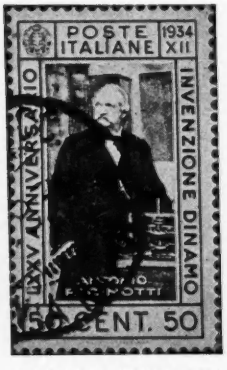

FIG. 17. Pacinotti [Italy 322].

FIG. 18. Gramme [Belgium 217].

FIG. 19. Tesla.

FIG. 20. Wireless station [Guatemala 168].

This solved the problem of connecting in series any number of the conductors of a multipolar dynamo. Although Pacinotti's armature was invented in 1864, it was re-invented in improved form by Zénobe Gramme (Fig. 18) about five years later. To Gramme goes the credit for producing the first commercial dynamo.

The American whose practical applications of physics probably have been more numerous and far reaching than those of any other individual is honored on a stamp [U. S. 654] issued in 1929 to celebrate the golden jubilee of Thomas A. Edison's "light in a bottle." Another American citizen with numerous electrical inventions to his credit is Nikola Tesla (Fig. 19), a native of Jugoslavia. For some time after his arrival in the United States he was with the Edison Company at Orange, N. J., a position which he relinquished in order to engage in research. The Tesla coil, the induction motor, new forms of dynamos, transformers, arc lights, and incandescent lamps are numbered among his contributions. Incidentally, the Tesla coil and similar devices provided the physical means for producing more readily detected radio waves. The first to utilize such waves for transmitting messages was the late Guglielmo Marconi, his first patent being granted in England in 1896. Marconi's horizontal directional aerial (Fig. 20) was patented in 1905.

During the first three decades of the present century researches in pure physics were largely concerned with the properties of the electron. The Dutch mathematical physicist, Hendrik Antoon Lorentz (Fig. 21), has been called the "father of the electron theory." Through the "Lorentz transformations" his name is connected with both the electron theory and relativity. An explanation of the Zeeman effect was offered by Lorentz soon after its discovery. Both men were awarded the Nobel Prize in 1902.

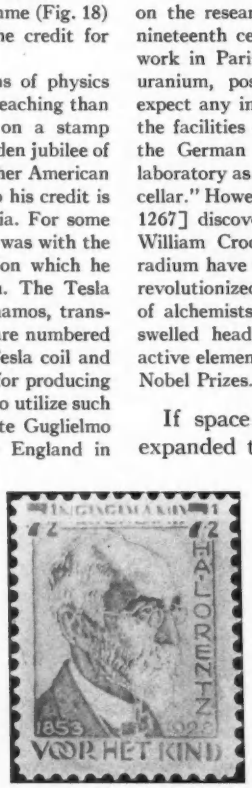

FIG. 21. Lorentz [Netherlands 487].

Some of the developments of modern physics are based on the researches of chemists. Toward the close of the nineteenth century an unknown Polish girl was hard at work in Paris trying to find other elements which, like uranium, possessed the property of radioactivity. To expect any important results was to ask a good deal, for the facilities of her laboratory were very crude. Indeed, the German chemist, Wilhelm Ostwald, described the laboratory as "a cross between a horse stable and a potato cellar." However, in 1898 Marie Sklodowski Curie [Turkey 1267] discovered an element which later prompted Sir William Crookes to remark that "A few decigrams of radium have undermined the atomic theory of chemistry, revolutionized the foundations of physics, revived the ideas of alchemists and given some chemists a bad attack of swelled head." For her efforts in the realm of radioactive elements Mme. Curie has been the recipient of two Nobel Prizes.

If space permitted this discussion could be expanded to include a number of phases of the science not touched upon here; for example, sound, cosmic rays, and applications of vectors. It is hoped, however, that the foregoing material is sufficient to demonstrate what can be done in building up a collection of truly scientific interest.

Nova Reperta

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ABOUT 1600 a charming set of twenty beautifully engraved plates, 10½ by 8 in., entitled *Nova Reperta* (New Discoveries) and illustrating the most important discoveries and inventions of the Middle Ages, was executed at Antwerp by PHILLIPP, THEODOOR and JOANNES GALLE from designs painted or sketched by JOAN. STRADANUS. As the fine prints from this interesting series of plates appear to be little known to teachers of the sciences in this country it may be worth while for me to describe briefly a set that has recently come into my possession. It represents one of the early attempts to describe the new scientific discoveries, attempts which have multiplied since that time almost as rapidly as have the new inventions themselves. And it is a peculiarly interesting attempt because it appeared at precisely the beginning of our modern scientific period and consequently portrays the state of science and invention, as well as the various trades and handicrafts, as they were before the "experimental method" was consciously and systematically used in either science or industry, and before the rapid acceleration in the rate of scientific invention brought about by the introduction of that method had begun.

JOAN. STRADANUS, a Flemish painter of note, was born at Bruges in 1523 (?). His real name was JAN or JOANNES VAN DER STRAET. After instruction by his father and by PIETER AARTSEN he went to Rome where he studied the work of RAPHAEL and MICHELANGELO to such effect that an exaggerated imitation of their style is evident in much of his own later work. Called to Naples by DON JOHN of Austria, he decorated DON JOHN'S palace with paintings and accompanied him back to the Netherlands. He soon returned to Italy, however, and settled in Florence, where he was called GIOVANNI DELLA STRADA. He produced a large number of paintings and pen-and-ink drawings and these were engraved to the number of 388. He died in Florence in 1605.

The GALLES were a famous Antwerp family of engravers. PHILLIPP GALLE (1537–1612), the founder of the family, was born at Haarlem, studied at Amsterdam, travelled in Italy, France and Germany, and finally settled at Antwerp in 1570 as an engraver and printseller. His two sons, THEODOOR (1571–1633) and CORNELIS (1576–1659) were taught engraving by their father, but went to Rome for further study before settling in Antwerp; they both acquired a skill greater than that of their father, and

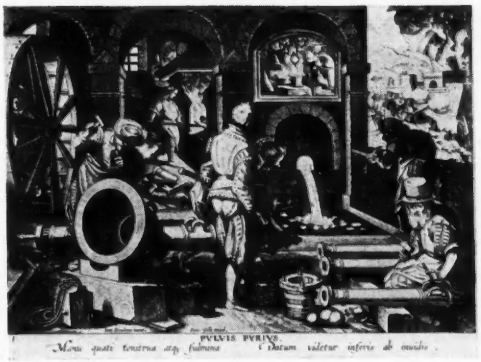

FIG. 2. Manufacture of cannon [Plate 3].

FIG. 1. Printing [Plate 4].

FIG. 3. Clocks and watches [Plate 5].

CORNELIS in particular is said to have "equalled the most famous engravers" and came to be regarded as the chief authority on the subject in the Netherlands. JAN or JOANNES GALLE (1600–1676) was the son and pupil of THEODOOR; he worked with his father and uncle and his name appears on many plates along with theirs.

I have examined two sets of the *Nova Reperta*, one in my own possession, the other in the Henry E. Huntington Library and Art Gallery, San Marino, California. All the prints in the Huntington Library copy are signed

while all but one in my copy are signed

Apparently the prints were popular enough in their own day so that JOANNES worked over his grandfather's plates. *Bryan's Dictionary of Painters and Engravers* assigns the plates to THEODOOR GALLE, but only one of the prints in either of the two copies accessible to me bears the imprint, "Theodor Galle sculp."

Every one of the twenty plates included in the *Nova Reperta* is extremely interesting and worthy of reproduction and comment. The discoveries and inventions portrayed are: The Continent of America, The Magnetic Compass, Gunpowder, Printing, Clocks and Watches, Guaiacum Wood as a Remedy for Syphilis, Distillation, Silk from Silk Worms, Stirrups, Water Mills, Wind Mills, Olive Oil, Sugar, Oil Pigments for Artists, Spectacles, The Determination of Longitude from the Declination of the Magnetic Compass, Armor Plate, the Astrolabe, and Copper-Plate Engraving. Each plate shows, with great accuracy and detail, the various tools and implements used and the processes followed. Thus printing (Fig. 1), copper-plate engraving, oil-painting, distillation, the manufacture of cannon (Fig. 2), clocks and watches (Fig. 3), sugar, and olive oil, the cultivation of the silk worm, etc., are shown very clearly as they were practiced in the sixteenth century. The shop of an oculist with his stock of spectacles of different types and their use by various people (Fig. 4) makes a most interesting picture. Quite different, but no less interesting, is the plate showing a man suffering from venereal disease and the preparation of the remedy, a decoction of guaiacum wood or lignum vitae, which, from 1508 until about 1800, was considered a certain specific for syphilis. A map of the American continent is given on the title-plate and the discovery of America is correctly attributed to COLUMBUS, with AMERICUS VESPUCCIUS as explorer and namer (Fig. 5).

FIG. 4. Shop of an oculist [Plate 15].

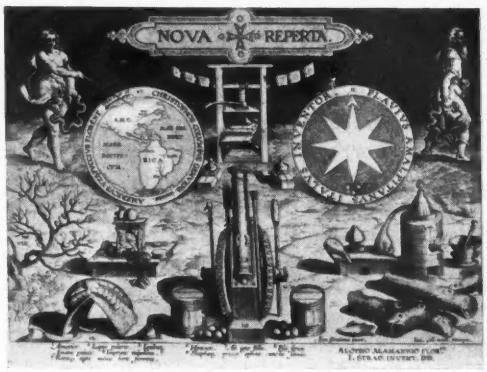

FIG. 5. Title-plate of *Nova Reperta*.

FIG. 6. The magnetic compass [Plate 2].

Figure 6, "The Magnetic Compass," shows the floating loadstone of the Middle Ages with a navigator studying its uses and surrounded by the various instruments of his profession. The legend under this plate, as well as that around the compass on the title-page, assigns the dis-

FIG. 7. Determining longitudes [Plate 16].

covery of the magnetic compass to FLAVIUS of Amalfi, Italy. As pointed out by SILVANUS P. THOMPSON in his article on the "Compass" in the *Encyclopaedia Britannica* (Ed. 11), this was a belief which took shape early in the seventeenth century and probably arose as follows. The historian, FLAVIUS BLONDUS (1388–1463), in his *Italia illustrata*, written about 1450, stated that the floating magnet (which was commonly used by Italian sailors at least as early as the twelfth century) was introduced by traders belonging to the port of Amalfi, but added that its origin was uncertain. In 1511, BATTISTA PIO, in his *Commentaries* repeated this statement as to the first use of the magnet and quoted FLAVIUS as his authority. GYRALDUS, while writing his *Libellus de re nautica* in 1540, apparently misunderstood this reference and stated that the pole-seeking property of the loadstone had been handed down as the discovery of "a certain FLAVIUS." As time went on this statement grew into the story "that the compass was invented in the year 1302 by a person to whom was given the fictitious name of FLAVIO GIOJA, of Amalfi." This is a good illustration of the way in which many popular beliefs have arisen. The real inventor of the magnetic compass remains unknown; in fact it is peculiarly characteristic of the so-called discoveries of the Middle Ages that when first

FIG. 8. The water mill [Plate 10].

mentioned by historians they are already in general use.

Figure 7, entitled "Orbis Longitudines Repertae e Magnetis a Polo Declinatione" (Longitudes Determined from the Declination of the Magnet) is also of especial interest. The legend reads "Magnete paulum utrinque saepe devia dat invenire portum ubique Plancius" (to find port anywhere by means of the slight deviation of the magnet to either side is the invention of PLANCIUS). PETER PLANCIUS (1552–1622) was a Flemish Calvinistic theologian, cartographer and astronomer and "a most diligent student, not so much of geography as of magnetic observations." He is now remembered chiefly, however, for the part he played in shaping the colonial policy of the Netherlands. He helped organize the West India Company, was the first to recommend the Dutch expeditions to both the Indies, and prepared the necessary instructions and maps to insure their success. It is interesting to find him here credited with the suggestion that the problem of determining longitude at sea could be solved by calculations based upon the declination of the magnetic needle. This suggestion, which has turned out to be erroneous, was apparently considered of great importance at the time it was made since it is here ranked with the invention of printing, gunpowder, etc. The idea was certainly shared, however, by TOUSSAINCTE DE BESSARD, GUILLAUME DE NAUTONNIER, ROBERT NORMAN and others, and THOMAS BLUNDEVILLE devotes several pages to it in his *Exercises* (London, 1594) without crediting it to anyone.

Several of the plates have an added interest because of the care and detail with which many of the tools and instruments of the period are delineated. Thus Fig. 8, entitled "Mola Aquaria" (The Water Mill), shows two steelyards in great detail. They are modern in type with fixed pin pivots and each instrument has two fulcrums, one for light, the other for heavy loads. The stop adopted to limit the movement is similar to that used in Roman times. Apparently in the sixteenth century farmers in the Netherlands carried their own steelyards with them when they took sacks of corn to the mill.

Taken as a whole these twenty plates, eight of which are reproduced here, give a beautiful as well as a fairly accurate picture of the state of science and invention at the very beginning of the modern period.

Areal Representation of Momentum and Energy

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A PROOF given early in some general physics courses establishes the basic equation for the energy of a body having motion of translation, $K.E. = \frac{1}{2}mv^2$. Those who find an alternative proof only an added burden will prefer to memorize such an equation, but there may be some students and teachers who will enjoy the following demonstration.

The usual derivation employs the expedient of a constant force applied to a body free to move. Here $W = FS$, and one avoids the necessity of summing up a series of small amounts of work, each of the form FdS. But we wish to make it plain that the final energy of the body depends only on its mass and speed, and not upon the manner in which the speed was imparted. To the beginner, not yet made familiar with this proof and tolerant by endless repetition, it seems a shameful thing to choose a particular process, and that the simplest one, and then to insist that the resulting energy would have been the same if the process of storing it had been different. However, the general expression for work is not FS, but the area between the S-axis, the ordinates marking the beginning and ending of the process, and the curve representing $F\cos\theta$ as a function of the distance S. Any one such curve, even if the expression $F\cos\theta dS$ can be integrated, represents a particular case, with acceleration constant or variable; and if integration is impossible, counting squares gives a numerical value but no general expression. The case in which the body gains its speed by a harmonic motion, while no more general, is not so simple as the case of constant acceleration, yet permits an easy summation. Here F is proportional to the displacement, and the work is $\frac{1}{2}$ *maximum force* $\times$ *amplitude*. Since $F_{\max} = MA_{\max} = M\omega^2R$, $W = \frac{1}{2}M\omega^2R^2 = \frac{1}{2}MV^2$.

All concern for the details of the accelerating process is unnecessary, however. Let the momentum MV of the body be represented by the ordinate and its speed V by the abscissa in a rectangular coordinate system (Fig. 1). If M is constant the resulting curve is a straight line through the origin, carried out as far as to the speed finally acquired. Consider a narrow vertical strip between the curve and the speed axis. The area a of the strip is approximately $MVdV$ or, if we prefer, MVv, where v is the small change in speed across the strip. Now $a = MVv = MVAt$, since the change in speed is the product of the instantaneous acceleration A and the time interval t required for the change. But Vt is s, the corresponding small distance, and since $MA = F$, $a = Fs = w$, the small amount of work corresponding to the small displacement. Therefore the whole area, the sum of all the strips, represents the total work done in bringing the body up to its final speed. Accordingly, $W = \text{area} = \frac{1}{2}$ base $\times$ altitude $= \frac{1}{2}V \cdot MV = \frac{1}{2}MV^2 = K.E.$ Evidently it makes no difference how the work was done. We have transformed any (or every) definite integral of the form $\int_{S=0}^{S=S} F\cos\theta dS$ (if $F\cos\theta = MA$) into the area of a triangle. With momentum and speed represented as in Fig. 1, all cases are included and the graph is a straight line, however "so confused, so strange, outrageous and so variable" the working force may be.

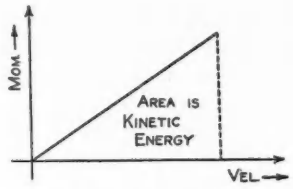

FIG. 1. MV *vs.* V.

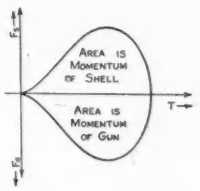

FIG. 2. (left) P and P' *vs.* t.

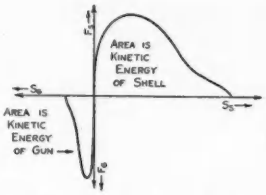

FIG. 3. (right) P *vs.* S_s and P' *vs.* S_g.

It is frequently explained that area represents distance if speed is plotted as a function of the time. But such a curve shows the peculiarities of the changing speed. In Fig. 1 all embarrassing details are avoided and the essential and useful features of the process alone employed. This illustrates the advantage of the transformation by which action is introduced and the whole of dynamics comprehended under a single principle.

It may be that any benefit of the foregoing argument will accrue to teachers of general physics rather than to students, but what follows has been in the writer's experience of help to both.

It is commonly said that the numerical equality of the momentum of a gun and the momentum of a discharged shell follows from Newton's third law of motion, that $F=-F'$. The beginner may have learned from the second law that $F=\{Mv-(Mv)_0\}/t$, but he is not prepared to deal with a varying force, and is confused by the complications of the process of expelling the shell. However, the third law expressly says that the forces (due to the pressure of the powder gases) on the shell and on the breech of the gun, though they may and do change continually, are always opposite and numerically equal. Part of each of these forces is necessary on account of friction, and not the entire force (gas pressure $\times$area) on the shell is to be used in computing its momentum or kinetic energy. If F and F', related by the third law as $F=-F'$, are the entire forces, and we subtract from each the force due to friction, called f, the opposite and numerically equal remainders are the active forces to be used in finding momentum and energy. Let $F-f=P$ and $F'-f=P'$. The force P is applied to the shell.

During any brief interval of time t (perhaps 10^{-6} sec.) during which P changes but little, Pt is the gain in momentum of the shell. Therefore we plot P as the ordinate and t as abscissa, as is done in Fig. 2, where the curves are drawn arbitrarily but with some tincture of reality. P' is plotted on the negative ordinate, numerically equal and opposite to P. Then the whole area—the sum of such strips as Pt—is the total momentum of the shell and the area beneath the time axis is the opposite and numerically equal momentum of the gun. If we have data secured in the ballistic work of the army these curves may be drawn to scale and counting squares will give actual momentum. To realize that momentum is given by the product of force and time, if force is constant, is an important gain, but to see that momentum is given by an area whether the force necessary on account of inertia is constant or variable is a further advance, and it helps a student to appreciate integration if and when he comes to study it.

One may go further. Measure the distances moved with respect to the earth, and plot that moved by the shell, S_s, as positive abscissa and that moved by the gun, S_g, as negative, and plot the effective forces P and P' as ordinates. This gives Fig. 3, which conforms roughly to experimental values. In this figure the distances and the two masses are in the unlikely ratio of 5 to 1. The enclosed surface in the first quadrant would have the same shape and size as that in the fourth if it were drawn to a different horizontal scale. The two areas represent kinetic energies of shell and gun and they are to each other inversely as the masses.

Really to prove that the curves of Fig. 3 are alike except for the different horizontal scales requires precise language. It is evident, if the forces are numerically equal, that the accelerations are numerically always in the inverse ratio of the masses. Two gains in speed made by shell and gun in any brief interval are therefore

inversely as the masses. Hence the two sums of the two series of gains, making up the two actual speeds at any time, are in this inverse ratio. Though the accelerations of shell and gun change continually, corresponding increments of the speeds of the two are in this fixed ratio and hence the accumulated speed of one (since both start from rest) is in that same ratio to the corresponding speed of the other. Thus in any brief interval the distance traveled by the shell is as many times as great as the distance moved by the gun as the mass of the gun is greater than that of the shell. The total distances traveled up to any time, accordingly, are in that same ratio, and hence one figure is like the other but uniformly shortened horizontally. The two areas, then, which measure the two amounts of work done, and the two resulting amounts of kinetic energy, are similarly related, or, finally, *K.E. of shell* is to *K.E. of gun* as *mass of gun* is to *mass of shell*. This is a valid proof which neither assumes a constant force nor deals with the vague concept of average force. Indeed Figs. 2 and 3 serve to explain the important idea that there is no unique average force. If the momentum imparted to a body is an average force multiplied by a corresponding time, and its kinetic energy is also an average force multiplied by the appropriate distance, then these two averages are in general different. They suggest indeed what amounts to a definition of the average value of a continuously changing quantity. Since we are unable to add an infinite number of separate values and divide the sum by infinity, we define an average force, the space average for example, as the area of either enclosed part of Fig. 3 divided by its base.

To emphasize the idea that accumulated speeds are in the same ratio as corresponding increments, one may cite the experience of James and John who begin life with no money. But every day John makes or loses 5 times as much money as James makes or loses. Then at the close of any day John has 5 times as much money as James, or is 5 times as much in debt, without exception if we grant that $0=5\times0$.

Speed of Pulses Along Tubes with Elastic Walls—An Artificial Artery

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A STUDY of the speed of a pulse along a tube with elastic walls, along a so-called *artificial artery*, will do much to convince the premedical student that physics really has something to do with medicine. A serious pedagogic difficulty in this problem of bringing out the connections between physics and medicine is, of course, that the beginner's meager technical knowledge of the one field is scarcely less than his professional knowledge of the other. In selecting the speed of a pulse for study, however, we are concerned with concepts familiar to the layman in either field. Further, such a study, which in all its ramifications offers a challenge to the theorist in the mechanics of deformable bodies as well as to the clinician to whom "age is to be reckoned by the state of the arteries," is sure to motivate both attention and enthusiasm in the tyro.

The medical man measures both a minimal and a maximal arterial pressure, the former occurring during the resting time of the heart and known as the *diastolic* pressure, the latter due to the intermittent pump-like action of the left ventricle and known as the *systolic* pressure. For a normal man in the middle forties, these pressures might be 85 and 130 mm of mercury, respectively. It is the difference between these two gauge pressures, however, that constitutes the pulse-wave, the speed of propagation of which concerns us here. The diastolic pressure, however, is not a fixed base above which the pulse pressure may be measured. It should be likened not to the hydrostatic pressure in a reservoir, but rather to the pressure in the pipes of a municipal water system. The output of the heart and the resistance of the terminal network of capillaries through which the blood leaves the arterial system are the fundamental factors determining this pressure, with the resiliency of the arterial walls and the volume and viscosity of the circulating blood as subsidiary factors. As blood pressures are usually measured in the brachial

artery at the level of the heart, variations due to height are not taken into account, although in the vessels of the lower extremities in the erect posture the diastolic pressure is greatly augmented by the effect of gravity.

The speed of the pulse wave must be clearly distinguished from that of the compressional wave which may travel in the liquid contained in the tube. This latter speed, essentially that of a sound wave, and how it is affected by the elastic tube walls, has received much attention at the hands of the physicist; but it was a physiologist, Moens, in 1878, who first derived the formula for the speed v with which a *pulse* is propagated along a tube, namely,

$$v=(Ed/2Dr)^{\frac{1}{2}}. \qquad (1)$$

Here E, d, and r refer respectively to the Young's modulus, the wall thickness, and the internal radius of the tube, and D to the density of the liquid it contains. The four simplifying assumptions underlying Eq. (1) are: (1) gravitational effects are negligibly small, (2) the liquid is incompressible, (3) the tube wall is perfectly elastic and of negligible mass, and (4) all displacements are small. In short, the idealized situation is that of a medium with axial symmetry, the inertia factor or mass being concentrated in the liquid core, and the stiffness factor or restoring force localized in the surrounding sheath of tube wall.

To realize these pulses in the elementary laboratory, one employs ordinary rubber tubing, $\frac{1}{8}$ in. inside diameter and $\frac{1}{32}$ in. wall thickness, filled with mercury. This simple arrangement is fittingly called an artificial artery because the speed of the pulse along it, about 5 m/sec., is of about the same magnitude as that found in human arteries; namely, 4 m/sec. in the brachial artery, and 8.5 m/sec. in the smaller artery between elbow and wrist.

If short lengths of tubing are to be used, the timing of the pulses must be done by the well-known method of condenser discharge. An 8-μf condenser charged to a fraction of a volt and discharging through an adjustable radio bleeder-resistance of some 50,000 ohm gives a proper time constant and sufficient deflection on a wall-type galvanometer. The mercury in the tube should form part of the discharge circuit to insure that no air bubbles have been trapped within it. One end of the tube is closed with a plug or a clamp and passes beneath the back end of the lever of a telegraph key. The spring actuating the key is adjusted so that the lever depresses the tube slightly. The other end of the tube is kept open and is turned up so that a needle can be set in contact with the free mercury surface. Simultaneously with the closing of the telegraph key and the starting of the condenser discharge, the pressure on the tube is released and a pulse is started on its way. When this pulse reaches the open end of the tube, the free surface of the mercury suddenly drops, contact with the needle is broken and the discharging of the condenser is interrupted. The charge remaining in the condenser is then compared with its initial charge and the time computed. Any lag in the action of the contacts may be eliminated by moving the key a known distance along the tube and noting the change in measured times.

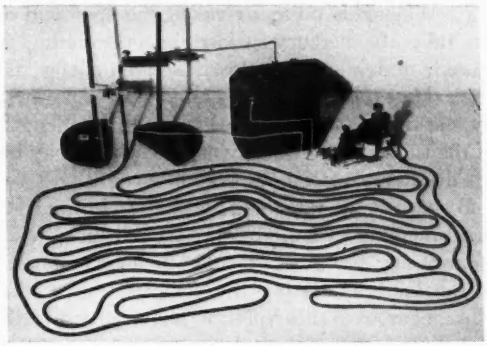

FIG. 1. A 50-ft. artificial artery arranged for self-maintained pulses.

For longer tubes, 5 m or more, an impulse counter actuated by the 60-cycle main offers sufficient accuracy. An even simpler way of timing is to set up a series of self-maintained pulses (Fig. 1). The needle at the open end of the tube is raised to a position slightly above the free mercury surface. This make-and-break contact is connected in series with a secondary battery and a telegraph sounder which now replaces the manually operated key at the closed end of the tube. When the contact is momentarily closed, the sounder is actuated and its lever presses against the tube, thus starting a pulse on its

way. When this pulse arrives at the open end of the tube, the mercury surface rises, the contact is closed, and another pulse is started along the tube. Thus the clicks of the sounder are separated by the time it takes a pulse to travel the length of the tube. The frequency of these clicks may be readily found with a stopwatch.

By any of the foregoing methods, v in the left-hand member of Eq. (1) may be measured with an accuracy of 3 or 4 percent. The determination of the factors entering the computation of the other member of this equation is straightforward. The dimensions of the tube are readily obtained from the weight of mercury it contains and the volume of water the filled tube displaces when completely immersed. Although rubber exhibits a more or less uncertain time lag between applied stress and resulting strain, by making measurements after an arbitrarily fixed interval of time, a fairly definite value for the Young's modulus may be obtained. It is advisable to use as small stresses as possible and to observe the strains with a cathetometer.

From the relation between the pressure of the liquid and the tension in the tube wall, together with obvious geometrical relations, the right-hand member of Eq. (1) may be transformed to $(B/D)^{\frac{1}{2}}$, where B is the apparent volume modulus of the liquid-tube system. The pressure coefficient of volume change entering this modulus is directly measurable by attaching to the open end of the rubber tubing a meter or so of uniform glass tubing of about the same bore. As the inclination of this tubing is varied, the change in height of the free mercury surface and its change in position along the tubing give, respectively, the pressure and the volume increments desired.

In addition to comparing the observed and computed speeds as outlined, the student may study the affect of changing the density of the liquid and of varying the ratio of wall thickness to tube diameter. Whenever the tube is stretched longitudinally the thickness and circumference of its wall shrink in the same ratio. Thus the ratio of d to r in Eq. (1) remains unchanged and the speed of the pulse does not vary as the tube is stretched. This fact has an obvious application when one considers the effect of bodily movements on human arteries.

If it is desired to set up a model that approximates the human artery still more closely, the rubber tubing may be joined to a water pipe by means of a gas cock. The cock is modified so that its valve can make a complete turn and is provided with a pulley or worm gear so it may be rotated slowly by a motor, thus turning the water on and off intermittently and sending a series of pulses along the tube accompanied, as in real arteries, by a flow of liquid. The part of the tube remote from the water pipe is fitted with several "T"s to which are attached short pieces of tubing partially plugged with capillary tubing or with adjustable pinch cocks. By increasing the resistance to flow in these outlet branches or by enlarging or speeding up the inlet valve, one may raise the level of pressure in the tube, the *diastolic* pressure. A simple U-tube manometer attached to the main part serves to indicate this pressure. If one of the outlet branches is fitted with a very flexible thin-walled piece of tubing, measurements of the systolic pressure may be made directly with a sphygmomanometer borrowed from a local physician. This outlet branch is laid on a board and wrapped with the armlet of the sphygmomanometer. The particular pressure at which the pulse below the armlet reappears as the pressure in the sphygmomanometer is released is the desired systolic pressure.

A more ambitious study of the form of the pulse wave, its damping and change of shape with passage along the tube, and in fact of nearly all phenomena associated with wave propagation, may be made with a sensitive quick-acting recording manometer applied to this artificial artery. A single reference[1] which contains an extended bibliography, is sufficient for those who may wish to carry experimentation further.

[1] Carl J. Wiggers, *The Pressure Pulses in the Cardiovascular System*, (Longmans, Green and Co.).

APPARATUS AND DEMONSTRATIONS

An Apparatus for Determining the Mass of a Body Without the Aid of Gravity

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A HORIZONTAL circular aluminum disk of about 35 cm diameter is mounted so that it may be rotated about a vertical axis through its center. The rotation of about 180 rev./min. is produced by means of a motor, preferably a synchronous motor provided with a suitable reduction gear.

A car about 13 cm long, preferably on ball bearings, is mounted over a radial guide (Fig. 1). This guide is narrower than the groove in the car except at the ends where it is wider so as to center the car. The car is provided with two vertical checks, for holding the body in two fixed positions radially on the car, one at the outer end and one about midway between the ends. These checks are a fixed distance d apart. From the car a string passes horizontally under a pulley at the center of the disk, preferably mounted on ball bearings, and then the string passes axially up to a swivel, also preferably on ball bearings. The swivel in turn is connected by a string vertically to the lower end of a vertical helical spring. At its lower and upper ends the spring is provided with guides having index lines for indicating their positions on a vertical scale at the side of the spring. The spring is supported by means of a string which passes vertically through a guide to a friction roller at the top about which it may be wound so as to support the spring in any vertical position. The friction roller is supported by two vertical bars, one on each side of the spring, and one of which carries the vertical scale referred to above. The whole is mounted on a suitable base and frame. The base is provided with leveling screws so that the disk may be placed in the horizontal position.

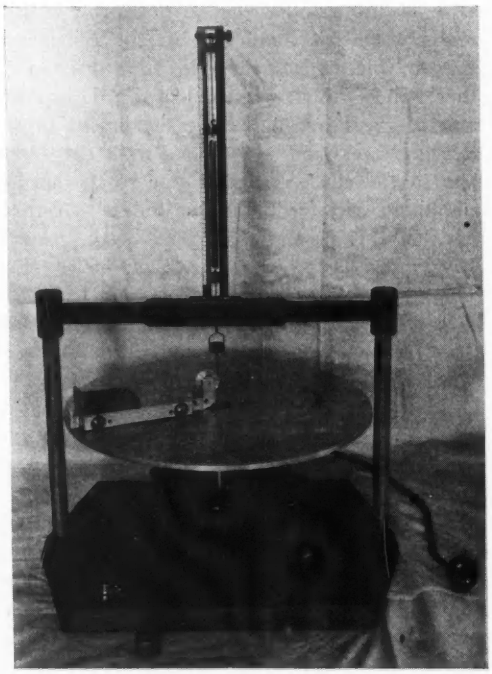

FIG. 1. Photograph of apparatus.

Procedure.—The body whose mass M is desired is placed on the car against the outer check. The disk is then rotated with a constant angular speed. By means of the friction roller the spring is raised or lowered until the lower index is at a point S_0 on the scale for which the car is over the narrow portion of the radial guide and is thus free of the guide. The position S_1 of the upper index is then observed.

The body is next placed against the check at the midpoint of the car and on the center side of this check. The car is then given the same angular speed as before. By means of the friction roller the lower index is again adjusted to S_0 on

the scale. The position S_2 of the upper index is then observed.

The same process is repeated with a standard body of known mass M_0 instead of the unknown mass M, and readings S_1' and S_2' for the positions of the upper index on the scale observed.

Thus knowing M_0, S_1, S_2, S_1' and S_2', we can determine the mass M of the body from the equation

$$M = M_0(S_1 - S_2)/(S_1' - S_2'). \qquad (1)$$

The derivation of Eq. (1) is as follows. If K is the constant for the spring and S the position of the upper index when there is no tension in the spring and the lower index is at S_0, then, with the body against the outer check,

$$(S_1 - S)K = M\omega^2 R_1 + M_c\omega^2 R_c, \qquad (2)$$

where M is the mass of the body, ω the angular speed, S_1 the reading on the scale for the upper index, R_1 the distance of the center of mass of the body from the axis of rotation, and M_c and R_c, the corresponding quantities for the car. Similarly with the body against the inner check of the car,

$$(S_2 - S)K = M\omega^2 R_2 + M_c\omega^2 R_c. \qquad (3)$$

Subtracting Eq. (3) from Eq. (2), we have $(S_1 - S_2)K = M\omega^2(R_1 - R_2)$ or

$$(S_1 - S_2)K = M\omega^2 d, \qquad (4)$$

where d is $R_1 - R_2$, the fixed distance between the checks on the car. In a similar manner, when a standard body of known mass M_0 is used instead of the mass M, we have

$$(S_1' - S_2')K = M_0\omega^2 d, \qquad (5)$$

when the same checks on the car are used as before. Dividing Eq. (4) by Eq. (5) and solving for M, we have Eq. (1).

It will be noted that the derivation assumes the accuracy of Hooke's law. This assumption does not involve the force due to gravity, however, because the law may be verified by means of this apparatus independently of gravity. For example, if a standard body in the form of a solid right cylinder be used, other solid cylindrical bodies of volumes 1, 2, 3, $\cdots$ n times the volume of the standard may be constructed of the same material as the standard. The elongation of the spring due to each of these bodies may then be determined, each body being in turn placed on the car so that its axis, that is, its center of mass, is at the same radial distance from the axis of rotation as in the case of the other bodies. A graph giving the relation between the number of standard bodies and the elongations may then be obtained, thus verifying the law and determining the constant K in terms of the specification for the absolute unit of force, i.e., the force which is the equivalent of the force that can give to a unit mass (standard body) one unit of acceleration. Or, similarly, several bodies may be constructed which will each give the same elongation of the spring when similarly placed on the car. Elongations of the spring may then be obtained, using 1, 2, 3, etc., of these bodies, and the law verified as above.

It is of interest to note that if K, the constant for the spring, is greater than $M\omega^2$, a point of equilibrium exists. For an arbitrary downward displacement of the lower index, the increment in the elastic reaction due to the spring will be greater than the increment in the centrifugal reaction, thus causing the index to return. On the other hand, for an arbitrary upward displacement of the lower index the decrement in the centrifugal reaction will be less than the decrement in the elastic reaction due to the spring, thus again causing the lower index to return. It is therefore possible by means of the friction roller at the top to adjust until the lower index is at the desired point S_0 on the scale for which the car is free. It has been found that about 3 rev./sec. is a satisfactory speed. At this low speed there is no perceptible pounding due to the excentricity of the rotating masses. It is desirable to mount the disk so that it will slip in starting in order to avoid stripping the reduction gear.

This apparatus gives the mass to an accuracy of about 1 percent. Its independence of force due to gravity and its dependence on the elastic reaction due to the spring and centrifugal reaction stimulates the student's interest when used as a demonstration in lecture or as a laboratory experiment.

The Specific Charge of the Electron

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AN accurate measurement of the specific charge of the electron can be obtained from the equipment described, which is used in a laboratory experiment in an intermediate course in *X-Rays and Nuclear Physics* and for demonstration purposes in elementary courses. The values obtained for e/m from individual measurements by students are within 2 percent of the accepted figure for this important physical constant. Historically[1] the method is of great interest as, in principle, it is the same as that described by A. Schuster[2] in 1890 and used by W. Kaufman[3] in 1897.

A beam of electrons is produced from a gun in which the electrons attain their full energy in falling through the potential difference between the hot filament source and the anode surrounding the coaxial filament.[4] Fig. 1 shows the gun in detail and the complete apparatus. The path of the electron beam deflected by the magnetic field of Helmholtz coils is rendered visible by the light produced by electron impact with the mercury vapor present in the bulb. Over the ordinary range of room temperatures the vapor pressure of mercury is ideally suited to secure an easily observable beam without excess scattering or a strong general background of diffuse light. Whatever the pressure of the mercury vapor may be, a good sharp beam can be produced by changing the filament heating current until the beam and slit widths are the same. The apparatus can be made to give a somewhat more intense

[1] J. J. Thomson, *Recollections and Reflections* (Bell, 1937), p. 332.
[2] Proc. Roy. Soc. **47**, 526 (1890).
[3] Wied. Ann. **61**, 544 (1897).

[4] The use of an electron gun of this type is an improvement over one common type of e/m apparatus in which a space charge sheath forms the anode. The energy of the electrons is not easily determinable in that apparatus as the difference of potential between the cathode and sheath is less than the externally applied accelerating potential by an unknown amount.

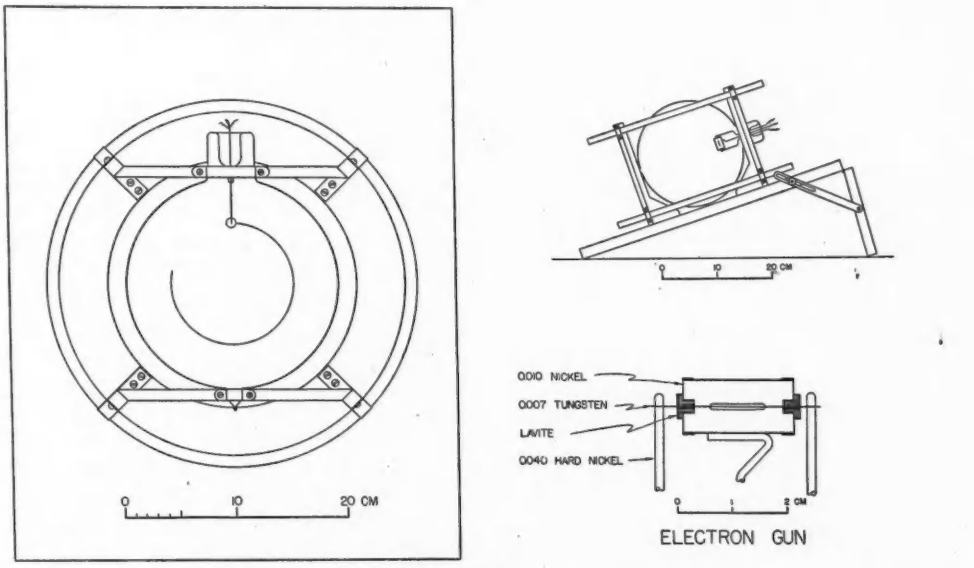

FIG. 1. Diagrams of the apparatus. The inch is the unit for the dimensions of the nickel and tungsten sheet and wire indicated in the diagram on the right.

and sharper beam at bulb temperatures below 18°C. A moist cloth in contact with the bulb allows satisfactory operation at summer temperatures.

The diameter of the electron beam is measured on a scale pasted to the surface of a mirror set under the bulb, parallel to the plane of the beam and to the central plane of the coils.

Three liters is a convenient size for the bulb. It must be thoroughly baked out and the metal parts outgassed by electron bombardment before admitting a mercury droplet and sealing off the bulb from the exhaust system. Any small residual pressure of carbon monoxide and air is very detrimental to the formation of a sharp beam of electrons.

The magnetic field is produced by Helmholtz coils, 36 turns each, of size 14 wire wound to a mean diameter of 32 cm. The planes of the coils are separated one-half their mean measured diameter. The axial field strength is given to a sufficiently close approximation by

$$H=(32\pi NI/(125)^{\frac{1}{2}}a)(1-d^2/15a^2) \text{ gauss}, \quad (1)$$

where a is the coil radius, d is one-half the radial depth of the winding, and N is the number of turns on a single coil. The correction for the finite dimensions of the coil is negligible compared to the correction for the reduced field strength at the position of the electron beam away from the axis of the coil. The field strength[5] in the central plane for any radius r away from the coil axis is

$$H_r=H_{\text{axial}}(1-54r^4/125a^4). \quad (2)$$

For a radius of 5 cm and coils of diameter 32 cm, the field is 0.4 percent less than the axial value. If space allows it is advantageous to double the radius of the coils so that the field strength correction is reduced to 1/16 of the former amount and can be neglected.

In a uniform magnetic field H, the force Hev on a moving charge is normal to its direction of motion and to H. This force constrains the electrons to a circular path in which the centrifugal force is mv^2/r. The energy of the electrons is $Ve=\frac{1}{2}mv^2$. Solving for the specific charge, we obtain $e/m=2V/H^2r^2$. If $V_{\text{acc.}}$ is the difference of potential applied between the anode and the positive leg of the filament, and V_f is the IR drop across the filament, then $V=V_{\text{acc.}}+\frac{1}{2}V_f$. The field H is the sum of the values of the earth's field and that of the coils. For accurate results, the earth's field must be measured where the instrument is placed, as it has in a laboratory a magnitude and direction differing from the tabulated values.

[5] H. Nagaoka, Phil. Mag. **41**, 377 (1921).

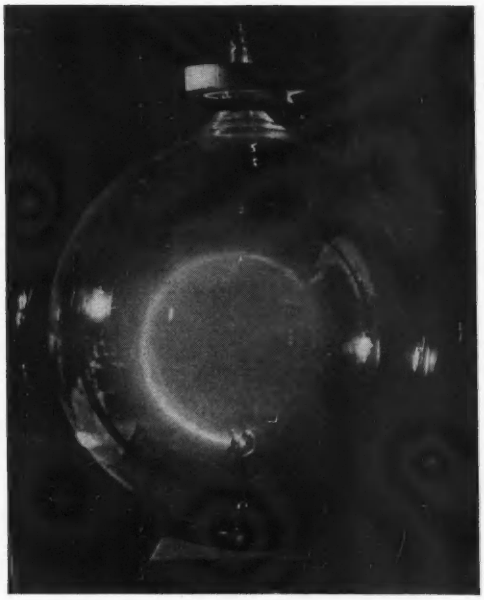

FIG. 2. Large demonstration apparatus with 22-l bulb.

In the laboratory, three to five determinations of the diameter of the electron beam are made for each of three values of the accelerating voltage, say for 80, 100, and 120 v.

With this same apparatus for the measurement of e/m, one can show the heating effect of the electrons impinging on the anode, the sidewise deflection of the electrons by the magnetic field of the filament heating current, and the deflection of the electrons by the earth's field.

Figure 2 is a photograph of a larger apparatus for use in the large lecture room. The electron gun is 2 cm diameter by 3 cm long with an aperture of 15 by 1 mm. A 0.007-in. tungsten filament is used here also.

Demonstrating the Rotating Magnetic Field

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IN demonstrating the rotating field vector the apparatus shown in Figs. 1 and 2 has been found very helpful. The coils A and B are Ford T-model induction coil primaries. They are connected through the reversing switches a and b to a potentiometer and cell so that a motion of the sliding contact S increases the current through one coil while it decreases the current in the other. The cell is a 1.5-v dry cell and the potentiometer has a total resistance of 4.2 ohm. A field-mapping compass M, 10 or 15 mm in diameter, is placed at the intersection of the axes of the coils.

By connecting only one switch at a time the student sees that the compass takes up the direction of the separate fields and hence, when both fields are present, will indicate the direction of the resultant field. Now, by moving the sliding contact S and by operating the reversing switches in the proper order, the compass needle may be made to rotate in either direction. Appropriate vector diagrams may be made and illustrated for various positions of the sliding contact.

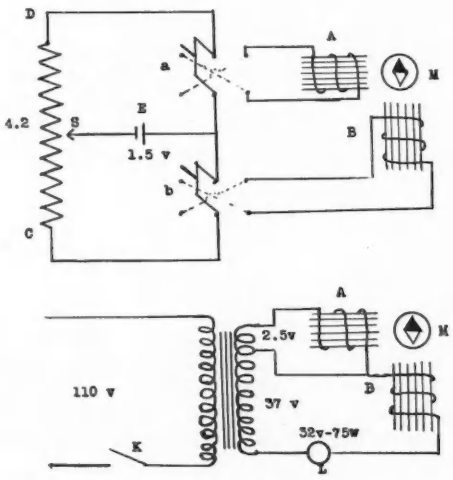

FIG. 1 (top) AND FIG. 2 (bottom). Diagrams of circuits.

In order to secure continuous rotation in one direction, switch a must be reversed while contact S is at C and switch b reversed while the contact is at D. If the current in a coil at the instant of reversal is less than the coercive current the field due to this coil will not be zero after reversal and a subsequent decrease of the current in the other coil will produce a momentary reversal of the direction of rotation. Because of this condition the potentiometer resistance must be kept small. Since the resistance of each coil is about 0.3 ohm, the current range for this circuit is from 0.2 to 2.5 amp. For these current values the magnetic field due to each coil is approximately a linear function of the current. It should be noted that the rotation of the needle is not a linear function of the displacement of the contact S.

The two coils are next connected to a split-phase circuit (Fig. 2). The 2.5-v filament winding of a Tungar rectifier transformer is connected directly to one of the coils while the other coil is connected to the 37-v winding through a 32-v, 75-w lamp. A 50-w lamp or a resistance of from 15 to 25 ohm would work as well. The two transformer windings have a common tap.

If the compass needle does not move on closing the switch K in the 110-v line, it may be started by rapidly opening and closing this switch. If the compass is illuminated by the light from a neon lamp connected to the alternating current used, the needle will appear to stand still for short intervals of time. Due to friction and to imperfect balance its speed is not constant. A very small compass gives best results.

The foregoing procedure illustrates the principle of the synchronous motor. The principle of the induction motor may also be demonstrated by suspending, by means of a thread, a conductor, such as an aluminum hub cap, in the rotating magnetic field.

The Spectroscopic Determination of Ionization Energies as a Laboratory Exercise

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THE determination of ionization energies is a good undergraduate project in spectroscopy. In the case of hydrogen this is simply a matter of evaluating the Rydberg constant. For other elements graphical methods may be used which should be readily understood by students who have studied the Bohr theory.

The spectrums of the alkali earths are next in simplicity to the spectrum of hydrogen. For convenience sodium may be taken as an example. A 110-v carbon arc is a convenient source if sodium chloride or metallic sodium mixed with carbon dust is packed into a hole in the lower electrode. The continuous spectrum from the carbon arc is not strong enough to be troublesome. Since the principal series of sodium lies largely in the ultraviolet, a quartz or grating spectrograph should be used. However, if only a glass spectrograph is available the ionization energy can be determined from measurements of the sharp and diffuse series together with the D lines, as these series lie almost entirely in the visible region.

The validity of the assignment of particular frequencies to a given series can be demonstrated by plotting $\tilde{\nu}$ as a function of $1/n^2$, where $\tilde{\nu}$ is the frequency in wave number units and n is the total quantum number. Such a curve for the principal series of sodium is shown in Fig. 1. The intercept on the frequency-axis is an approximation to the term value of the final state of the series. Hence approximate term values T of the initial states may be calculated by subtracting the wave number of each spectral line in the series from the term value of the final state. The quantum correction Q may then be calculated by using the Rydberg expression, $T=R/(n-Q)^2$, where R is the Rydberg constant for an infinitely massive nucleus. Now if $\tilde{\nu}$ is plotted against $1/(n-Q)^2$, the straight line shown in Fig. 1 results. This makes a more accurate determination of the series limit possible. No correction is necessary in the case of the diffuse series as the plot of $\tilde{\nu}$ *vs.* $1/n^2$ shows very slight curvature, which illustrates the effect of the eccentricity of the electron orbit on the magnitude of the quantum correction.

The energy of ionization E, in electron volts, may be calculated from any of these three series, as follows:

$E=(1/8106)$ Convergence wave number of P series,
$E=(1/8106)$ (Convergence wave number of S series+Av. wave number of D lines),
$E=(1/8106)$ (Convergence wave number of D series+Av. wave number of D lines).

If the doublets are resolved the student can easily determine which combinations to take by reference to his energy level diagram.

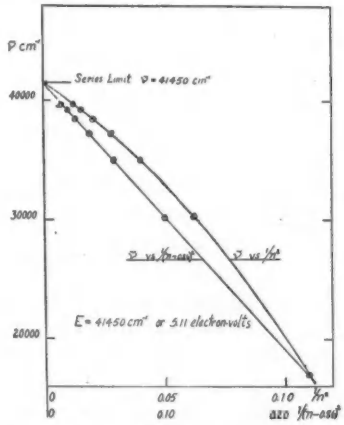

FIG. 1. $\tilde{\nu}$ *vs.* $1/n^2$ for P series of sodium.

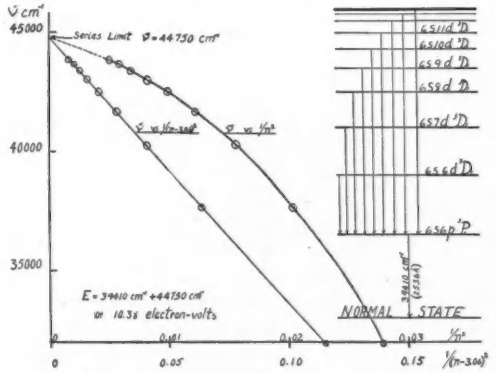

FIG. 2. $\tilde{\nu}$ *vs.* $1/n^2$ for mercury, and ionization energy.

It is instructive to make a study of the mercury spectrum in connection with the ionization potential experiment described by T. R. Cuykendall.[1] Most laboratories are equipped with suitable mercury arcs so that the task of photographing the spectrum is an easy one. The student is not expected to analyze this rather complicated spectrum without considerable assistance. Any series whose final state is the initial state of one of the resonance lines (2536 or 1849A) may be used to determine the ionization energy. The series assignments may be verified by plotting $\tilde{\nu}$ as a function of $1/n^2$, the quantum corrections calculated, and the series limit determined from the curve for $\tilde{\nu}$ *vs.* $1/(n-Q)^2$ as before. Typical curves, and a calculation of the ionization energy of mercury, are shown in Fig. 2. The description of experiments on the spectrums of sodium and mercury given by Harnwell and Livingood[2] is helpful. The procedure is clarified by the construction of energy level diagrams showing only the transitions involved.

[1] Am. Phys. Teacher **4**, 93 (1936).

[2] *Experimental Atomic Physics* (McGraw-Hill, 1933).

Projection Centrifuge

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I FIND that it is always stimulating to a student to see a liquid clarify under the action of the centrifugal force, for example, as in a centrifuge. This is especially true if the clarification is shown by projection on a screen. Such a projection is possible with the apparatus shown in Fig. 1.

A cylindrical cell about 10 cm in diameter is provided with plane, parallel, glass sides held in place by a frame which has a bearing surface on each side of the circumference and a V-groove for a belt so that it may be rotated. The cell has two small holes near each other in the periphery, closed by means of screws, through one of which the cell may be filled with the liquid by means of a pipette. This cell is mounted on a vertical support provided with a ¼-hp electric motor capable of giving the cell a speed of about 400 rev./min. The stand is designed so that the cell may be placed before the condenser of a projection lamp.

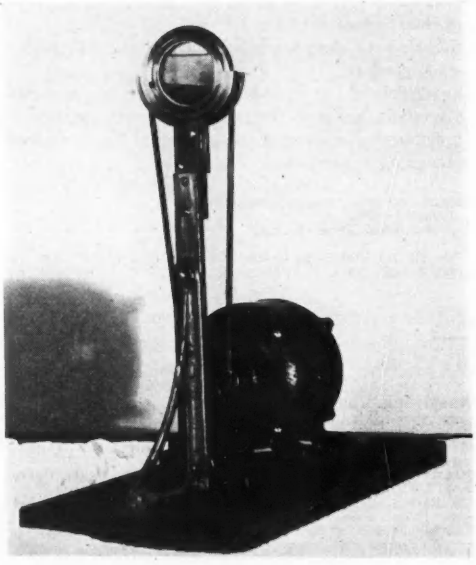

FIG. 1. Photograph of centrifuge.

It is not desirable to fill the cell completely. When the cell begins to rotate the enclosed air will pass to the center and a clear spot will appear at the center of the image of the cell on the screen. If a suitable liquid suspension is used the image will gradually clarify from the center outward until the whole is clear. After a rather lengthy search it was found that *lotus alba*, as sold at drug stores, is suitable for the purpose. This liquid will turn dark when left in the cell, thus increasing the contrast.

One difficulty encountered was due to the packing at the periphery under the centrifugal action, so that the particles would not return into suspension when the rotation ceased. This difficulty was overcome by placing a small irregular piece of lead of about 2 g mass in the cell. When the rotation ceases this piece of lead will, through its inertia, remove the particles from the periphery.

DISCUSSION AND CORRESPONDENCE

The Position of the Image of an Object Under Water

WHERE the fisherman sees the fish, or some similar question, is considered of sufficient interest to be discussed in many general physics texts. It is then surprising that few of those that furnish a diagram put the image, as seen from air, of an object under water in the correct place, that is, both nearer the surface and displaced sidewards *toward* the observer. This suggests that not many have tried the graphical method of locating the image by finding the point of intersection of two refracted rays that emerge near the same point of the surface.

It is easy to show analytically that if the object is at a distance h below the surface, and the origin be taken in the surface vertically above it, with the x-axis in the surface, then two rays emerging in the vicinity of the point (x, O) will intersect at the point

$$\left(\frac{7x^3}{9h^2}, -\frac{3(h^2-7/9x^2)^{\frac{3}{2}}}{4h^2}\right);$$

that is, the eye placed in position to receive such rays will see the image at this latter point. The sidewise displacement $7x^3/9h^2$ is small when x is small compared with h, but evidently increases with increasing obliquity of observation. For example, if a small object 6 cm below a water surface is observed by rays emerging at a point where x is 6 cm (angle of incidence on the water side, 45°), the image is more than 4 cm closer to the eye than the point O vertically above the object. This may be confirmed by making oneself artificially shortsighted with a lens so that an object at O cannot be seen distinctly, and at the same time one 4 cm nearer can be. The image will then be found to be distinctly visible. This is a more convincing type of experiment for some than the method of locating the image by eliminating parallax between it and a pin suitably held in air.

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Use and Meaning of the Term Heat

THE article by Witmer and Bushkovitch[1] merits the careful study of all teachers of physics. I wish particularly to emphasize the authors' requirement IV, which states that it is undesirable to have a given term used in more than one sense. One illustration of a widespread violation of this principle which is responsible for a serious confusion, is the use and meaning of the term *heat*.

In the heat section of most physics texts the word *heat* is early and carefully defined as the energy in a substance as represented by molecular activities or configurations. The idea that *heat* means energy in a body is thoroughly established. Later, when the energy relation $Q+W=\Delta U$ is introduced, it becomes necessary to use the expressions *internal energy* or *intrinsic energy* to mean the energy U in a body, and let the name *heat* now refer to that energy Q which enters the body by radiation or conduction.

Later in the subject *heat* is used *ad lib.* to mean (a) the kind of energy represented by the symbol Q, (b) the kind of energy represented by the symbol U, and also (c) the function $U+PV$, under the name *total heat* or *heat content*.

The confusion which results from the multiple use of the word heat may be avoided by the following nomenclature and symbolism:

Heat, to designate energy in transition from a hot to a cold body, with the usual symbol Q;

Internal energy, to designate the energy stored in a body, with the symbols E or U;

Enthalpy, to designate the function $U+PV$, with the usual symbol H.

Regardless of the desirability of having standard names and symbols, however, the practice of using the term heat as a synonym for internal energy should be abandoned in the teaching of physics.

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[1] "On the Lack of Logic in the Literature of Physics," Am. Phys. Teacher **5**, 145 (1937).

Program of the Western Pennsylvania Chapter

The Western Pennsylvania and Environs Chapter of the American Association of Physics Teachers met at the Carnegie Institute of Technology, Pittsburgh, on November 6. The following program was presented:

Two Demonstrations in Acoustics, CHARLES WILLIAMSON, *Carnegie Institute of Technology.*

An Infra-red Laboratory, C. E. LEBERKNIGHT, *Carnegie Institute of Technology.*

More on Physics Definitions and Units, H. W. HARMON, *Grove City College.*

Standards in Grading, with Particular Reference to the Curve of Normal Distribution, GEORGE E. DAVIS, *Duquesne University.*

The Earth's Electric Field and Some Related Phenomena, M. C. HOLMES, *West Virginia University.*

The Mechanism of Energy Loss in Magnetic Hysteresis, G. S. SCOTT, *University of Pittsburgh.*

Lectures in Elementary Physics in a Small College, J. A. SWINDLER AND J. G. MOOREHEAD, *Westminster College.*

Training of Physics Students for Industry and Teaching, a general topic suggested by W. H. MICHENER, *Carnegie Institute of Technology.*

Proceedings of the American Association of Physics Teachers

The Indianapolis Meeting, December 27–29, 1937

THE seventh annual meeting of the American Association of Physics Teachers was held at the Indianapolis Athletic Club, Indianapolis, Indiana, on December 27–29, 1937. The presiding officers were F. K. Richtmyer, President of the Association, and H. B. Lemon, Vice President.

At the dinner held jointly with the American Physical Society, President Richtmyer and D. L. Webster, Chairman of the Committee on Awards, presented the 1937 A. A. P. T. Award for Notable Contributions to the Teaching of Physics to *Edwin Herbert Hall*. The ceremony, which included an address of acceptance by Professor Hall, is described elsewhere in this issue. Other speakers at the dinner were H. M. Randall, Lyman J. Briggs, and G. W. Stewart.

Invited Papers and Reports

The following invited papers and committee reports were heard at two of the sessions:

A Species Almost Extinct. Theodore S. Rowland, *Northeast High School, Philadelphia, Pa.*

Unfinished Business for Physics Teachers. Alpheus W. Smith, *Ohio State University, Columbus, O.*

Acoustic Experiments in the Teaching of Optics, A Demonstration Lecture. Harold K. Schilling, *Union College, Lincoln, Neb.*

Report of the Committee on the Training of Physicists for Industry. P. I. Wold, *Union College, Schenectady, N. Y.* (Read by L. A. DuBridge.)

Report of the Committee on the Teaching of Geometrical Optics. J. Rud Nielsen, *University of Oklahoma, Norman, Okla.*

The first two of the foregoing papers composed a symposium on *College Physics in its Relation to Pre-College Education* and were followed by a discussion led by K. Lark-Horovitz, Purdue University, Lafayette, Ind.

Three invited papers were presented at the joint session with Section B, A. A. A. S., and the American Physical Society:

Neutrons—A Review. George B. Pegram, *Columbia University, New York, N. Y.*

Spectroscopy of the Far Infra-Red. H. M. Randall, *University of Michigan, Ann Arbor, Mich.*

Some Recent Progress in the Understanding of Nuclei. G. Breit, *University of Wisconsin, Madison, Wis.*

Contributed Papers, with Abstracts

Two sessions were devoted to the following contributed papers:

1. Student Opinion of the First Year College Physics Laboratory Experiments. C. J. Overbeck, *Northwestern University, Evanston, Ill.*—A study was conducted during the past several years to determine what features of a laboratory experiment make it, in the opinion of the student, of most value. On an unsigned questionary the student was given an opportunity to classify the finished semester's experiments as *good*, *fair*, or *poor*, and to add any candid remarks which he considered pertinent. He was also asked to select the two experiments which he thought had been of most value to him and the two which he considered the poorest, and to give reasons for each selection. Likewise he was encouraged to suggest changes which he believed would make the work of greater benefit to future classes. These statements have been analyzed and classified to give a composite picture of the type of experiment which these students indicated would be of most value. Especially numerous were remarks concerning types of subject matter which needed laboratory work as an aid towards understanding or acceptance, and remarks on the interrelation of fundamental laws, practical applications, accuracy of results, and the procedure used in the laboratory work.

2. A Study of the Learning Effectiveness of a Sound Motion Picture in College Physics. C. J. Lapp, *University of Iowa, Iowa City, Ia.*—Many findings have been made concerning motion-picture effectiveness as a teaching technic for school pupils, but little similar work has been done on a college level. The new sound film *Electrodynamics* produced by Erpi Picture Consultants was studied in detail to find: (1) The learning produced by two showings of the film; (2) The effect of an additional stimulus to learning in the form of a study sheet to be used during the class hour when the picture was shown; (3) The variation in the first two effects with class quartiles; (4) The ability to transfer new learning to specific situations not used in the picture; (5) The effect of knowing facts about a principle on the ability to transfer and use the principle in a new situation. Within the limits of the technic used, it was found that: (1) The teaching effectiveness of this sound film was considerably increased by the supplementary use of a study sheet; (2) The study sheet decreased the teaching effectiveness in some areas; (3) The study sheet had its greatest effectiveness in next to the highest quartile; (4) The study sheet confused many students in the lowest quartile; (5) Certain strengths and weaknesses in the teaching power of the film *Electrodynamics* are pointed out; (6) There is evidence that the greater the "sureness" an individual has about a fact or group of facts, the more likely he is to use it in a transfer situation.

3. Correlation Coefficients in Small Classes Using Essay- and Cooperative-Type Tests. L. B. Ham, *University of Arkansas, Fayetteville, Ark.*—A comparison has been made of the correlation coefficients between essay-type tests and the physics tests issued by the Cooperative Test Service. Considerable information has been accumulated to indicate that the essay-type tests are relatively unreliable because of the difficulty of establishing any uniform system of grading and because of certain misleading psychologic factors. For the past four years a series of essay-type tests

have been given to two classes in general physics at intervals of three or four weeks. Each class consisted of about 25 students. These tests were made up by the author and usually covered the material discussed since the previous test. The Cooperative physics tests were given as final examinations. From the 163 calculated correlation coefficients for the essay tests and for the Cooperative tests, the results indicate that the correlation coefficients are of the same order of magnitude, except possibly for the first essay test given and the shorter Cooperative tests. Of the 67 correlation coefficients between the pairs of essay tests and the final accumulative score for all examinations, the correlation coefficients for 8 pairs were below 0.5, 13 below 0.6, 25 below 0.7, 40 below 0.8. Similarly, of 40 correlation coefficients between the Cooperative tests and the final accumulative score, the correlation coefficient for 3 pairs were below 0.5, 9 below 0.6, 19 below 0.7, and 28 below 0.8.

4. A Simple Test for the Preciseness of a Definition of a Physical Term or Quantity. A. G. Worthing, *University of Pittsburgh, Pittsburgh, Pa.*—The test proposed is included in the statement: a definition of a term or quantity is an expression stated in simpler or more fundamental terms or quantities, which may replace the term or quantity wherever used without loss or change of thought. Mathematically it takes the form $X = Y$, where X signifies the term defined, Y the definition, and the equality sign the connecting word "is." As a corollary, it follows, for any case where a physical quantity is discussed, that the precise answers to the two questions, "What is X?" and "What is Y?" must be *identical*. The X, Y test has been applied to the definitions found in several texts and many have been found wanting. A proposed remedy includes the consideration of definitions that by themselves are too abstract for the ordinary student. The complete paper will appear in the April, 1938 issue of *The American Physics Teacher*.

5. The Suitability of Photography as a University Credit Course in Physics. J. E. Mack and M. J. Martin, *University of Wisconsin, Madison, Wis.*—The increasing demand for a college course in photography raises the question of the feasibility of giving such a course of unquestioned university grade without imposing prerequisites that would deny the course to those demanding it. For thirty years a two-credit course in the science and practice of photography has been a regular part of the curriculum of the physics department of the University of Wisconsin. We have found that a thoroughly scientific course, definitely on the college level, can profitably be given to students who have had no college physics and no previous experience in photography, the only prerequisites being elementary algebra and geometry. This course has proved to be both a popular elective and of particular value to specialized groups such as engineers, science majors, and students of the fine arts. A few of the examples of points of contact with physical theory are found in the treatment of thick-lens optics, diffractions and resolving power, the exponential nature of light absorption, theory of the latent image, spectral characteristics of sources, mediums, and emulsions.

6. A Two-Year Program in General Physics. Clarence E. Bennett and Karl D. Larsen, *University of Maine, Orono, Maine.*—In recognition of the fact that general physics has outgrown the conventional one-year course, a two-year basic program is presented. It is the plan now in effect at the University of Maine and is designed to give the student a thorough grounding in the general subject before he specializes in its various branches. An introductory course in the first year is followed by an intermediate course in the second year in which the general subject is treated again. In reality, two introductory courses are offered, either one of which constitutes the first year of this program. The one is a 10 semester-hour course that includes ample problem drill for engineers; the other is an 8 semester-hour course for those whose schedules will not allow the longer one. The latter course differs from the conventional Arts course in several unique respects. It is built around the same, identical two lectures per week given for the longer course, thus economizing on staff and at the same time emphasizing the view that "physics is physics;" it is thus conceded that courses may differ in length but that there is no essential difference in kind between so-called "Arts" and "Engineering" physics. A second feature is that no single textbook is used; reading assignments are made in various texts and unity is achieved by the use of a printed outline serving as a lecture syllabus. The laboratory work in the two courses is essentially the same. The second year of the program is a course in intermediate general physics covering the subject a second time but in a more analytic manner. This course is a practical and successful application of a proposal made by the senior author in Am. Phys. Teacher **2**, 158 (1934). A second-year laboratory course is also proposed to supplement this intermediate program. The emphasis of the whole program is placed upon general physics with the thought that the student will thus acquire a sound background for entering the advanced work with a proper appreciation of the analytic technics, the nature, and the scope of the subject as a whole.

7. A Suggestion for a New Second-Year Course in Physics. C. J. Lapp, *University of Iowa, Iowa City, Ia.* (By title.)

8. The Electrical Researches of Cavendish. R. J. Stephenson, *University of Chicago, Chicago, Ill.*—Due to his personal eccentricities Cavendish published practically nothing of his researches in electricity. His notes remained in manuscript form for nearly a century until they were edited and published by Maxwell. It was at that time that Maxwell discovered and repeated Cavendish's famous experimental proof of the inverse square law for electric charges. The present paper discusses briefly the methods and results of three of Cavendish's important contributions to electricity: (1) Measurements on the capacitance of condensers and the specific inductive capacitance of a number of common insulators. The accuracy which Cavendish attained may be illustrated by the fact that his experimental value for the capacitance of a circular disk of radius a was $a/1.57$ whereas the value now calculated is $2a/\pi$ or $a/1.571$.

(2) Measurements on the resistance of electrolytes which he obtained by discharging condensers through his body in series with a known amount of the electrolyte. The results obtained may readily be transformed into the form given by Ohm some fifty years later. Cavendish was also familiar with the laws pertaining to resistances in series and in parallel, (3) Two methods of checking the inverse square law for electric charges. These three experiments will be illustrated by diagrams from Cavendish's original notes which show that while his apparatus was quite crude, the methods and ideas were those of a genius.

9. College Physics as a Requirement for Entrance to Dental School. Eugene W. Skinner, *Northwestern University Dental School, Evanston, Ill.*—The applications of physics in dentistry are numerous and important, and the need for the teaching of physics to dental or predental students is fully recognized by all dental educators. In spite of this fact, many well recognized dental schools do not require college physics for entrance because of a feeling that existing physics courses occupy too much time with various demanded prerequisites and with the teaching of material considered valueless to the student in dentistry; it is felt that such time is out of proportion to the benefit received in lieu of a broader education in the languages and humanities, which is the aim of the requirement for two years in liberal arts for entrance to dental school. The American Association of Dental Schools has proposed that a course in physics be set up in the dental curriculum, and an outline has been prepared for such a course. Perusal of the outline indicates that the proposed course does not differ greatly from the course offered to premedical students in many liberal arts colleges. Furthermore, a study of university and college catalogs shows that satisfactory courses in college physics without prerequisites are offered in the majority of schools. The modern trend is for the requirement of college physics for entrance by all dental schools, inasmuch as the present dental school curricular content does not allow time for the proposed course. A course of study adaptable to the physics courses in the liberal arts college is suggested, and the portions of the course which should be emphasized are indicated.

10. The "Pressure Energy" Idea—Still Prevalent, Still Wrong! G. A. Van Lear, Jr., *University of Oklahoma, Norman, Okla.*—Although he was not the first to do so, the author pointed out in Am. Phys. Teacher **4**, 99 (1934) that the many elementary textbooks which derive Bernoulli's equation by use of the "pressure energy" idea make two serious, even though compensating, errors, for an incompressible liquid does *not* possess energy because of its pressure. Since 1934, three of the textbooks cited for these errors (Miller; Spinney; Kimball-Wold) have appeared in new editions in which the passages criticized have been replaced by unobjectionable material; the criticism thus seems to have produced the desired effect in some cases. On the other hand, three others cited (Duff; Erikson; Knowlton) have reappeared without essential changes in this regard, five new books (Hausmann and Slack; Culver; Hobbie; Eldridge; Williams) contain treatments of the type criticized, and forms 1935B and 1937A of the "Cooperative Physics Tests for College Students" each include a question based on the concept of "pressure energy." Renewed efforts thus seem to be necessary if this type of treatment is to disappear. In addition to calling attention to the situation just outlined and presenting what seems to be the best case which can be made *for* use of the "pressure energy" concept, the present paper treats certain points raised in private correspondence. The conclusion is that use of sufficient restrictions and explanations to make introduction of the "pressure energy" concept defensible would far more than cancel the advantage of brevity in deriving Bernoulli's equation, which is its only virtue. As they stand, all the treatments examined which utilize this concept are unsound.

11. An Adapted Demonstration Method of Laboratory Instruction. E. C. McCracken, *Iowa State College, Ames, Ia.*—This paper is a report of an investigation concerning the advantages and disadvantages of an instructor-supervised demonstration-type of laboratory as adapted for a second physics course which follows a general, freshman course of one quarter's duration. Information is included concerning the necessary instructor preparation, the conduction of the laboratory, and the value of this type of laboratory in determining the kind of work best suited to the individual student.

12. Material Which Teachers of High School Physics Feel They Need. Lester I. Bockstahler, *Northwestern University, Evanston, Ill.*—Last spring the physics teachers in the Illinois secondary schools were asked to express opinions on the training and teaching materials which they felt would aid them most in becoming more effective teachers of physics. Slightly over half of the teachers of the State responded. In the replies the following needs were emphasized: 85 percent desired further information as to how and where the principles of physics were applied in industry and in daily life; 80 percent felt a need for a simple exposition of the recent developments and theories in physics together with their implications; source material for the demonstration of physical principles seems widely lacking; about two-thirds of the teachers wished practice and information in demonstration and manipulation, including the construction of simple apparatus; about the same number felt they needed further training in laboratory technics and methods. Comments and suggestions from the teachers indicated their desire to have this material offered in special courses in departments of physics. There was a distinct desire for a book or series of pamphlets giving simple and specific information on source material and on the construction of demonstration apparatus. A volume dealing directly and specifically with how and where principles of physics are applied and manifested in daily life, in industry, and in other sciences would be highly acceptable. Teachers emphasized the fact that such information of this nature as now exists is widely scattered and poorly organized for the use of the secondary school teacher, who at best has little time or means for collecting it.

13. The Highway Mirage. Frank L. Verwiebe, *Eastern Illinois State Teachers College, Charleston, Ill.*—The illusive appearance on highways of regions of wet surface noticeable at small grazing angles is a refraction phenomenon due to a layer of heated air adjacent to the highway surface. As a first approximation this heated layer of air may be considered as a medium of a smaller index of refraction than that of the air above it, and using average values the phenomenon may be treated as an example of total reflection. To the ratio of the two indexes of refraction there then corresponds a critical grazing angle, which is formed by the line of sight and the plane of the road surface at the point where the mirage ceases to be seen. If, in the expression $\sin i_c = 1/n$, we substitute $\cos c$ for $\sin i_c$, c being the critical grazing angle and in general very small, there results the expression $(n-1) = c^2/2$. On the other hand, the dependence of n, the index of refraction for air, on temperature as given in the *International Critical Tables* is $(n_0-1) = (n_t-1)(1+\alpha t)$, where n_0 is given as $1+292\times10^{-6}$ for 5500A and 0°C, and α is 1/273, the gas constant. Letting $n = n_{t1}/n_{t2}$, we can show that $(n-1) = \alpha\beta(t_2-t_1)$, where β is 292×10^{-6}. From this it follows that $(n-1) = 1.07\times10^{-6}\,\Delta t$. Observations were made on a stretch of highway near Charleston to determine whether the two expressions gave the same value for $(n-1)$. The elevations of points along the road necessary to measure the critical grazing angles were obtained and a series of temperature readings at various levels in the air above the road surface were made on different days. The results show agreement for the two methods of measuring $(n-1)$ within the limits of experimental error. The maximum value of $(n-1)$ found was approximately 3×10^{-6} for a difference of average temperature values of 3°C corresponding to a critical grazing angle of 2.8×10^{-3} radians.

14. Lens Testing with a Spectrometer. Everett F. Cox, *Colgate University, Hamilton, N. Y.*—Attachments have been constructed to transform a student spectrometer into a lens testing device. The lens mounting which replaces the prism table consists of a fixed horizontal plate with a similar plate on it movable in one direction, the top plate carrying uprights for supporting the lens. The collimator is replaced by a simply supported vernier caliper scale and slide carrying a set of cross hairs; it is desirable that the scale read the distance of the cross hairs from the axis of the spectrometer. With the telescope focused for parallel rays, the lens mounted and roughly aligned with the telescope and cross hairs, the student moves the cross hairs into focus, and by successive trials with small angular movements of the lens, sliding of the lens mount and equal sliding of the cross hairs, soon fixes the nodal point nearest the cross hairs on the axis of the spectrometer. The optical axis of the lens may well be assumed at the angle halfway between field cut-offs. With the lens thus mounted it is easy to measure spherical aberration, and to measure and plot graphs of astigmatism and curvature of field. These three experiments performed by the students on their own camera lenses, greatly aid in the teaching of optics and photography.

15. An Experiment in Diffraction for Premedical Students. J. C. Stearns, *University of Denver, Denver, Colo.*—In this experiment the ruled grating is replaced by a blood smear. Blood containing red blood corpuscles of normal size is used for one smear, while blood from a person having pernicious anemia is used for another. One smear is also prepared where the cells are too close together and "chains of cells" or rouleaux result. A 200-w motion-picture lamp housed in a box with a pinhole opening serves as a light source. Either white or monochromatic light may be used. A lens produces parallel light which falls on the blood smear placed in front of the lens of a suitable box camera. The diffraction rings are formed on a ruled ground-glass plate. The diameters of the rings are measured and the average distance between red blood cells computed. These same smears are now observed with a microscope and the distance between cells measured. The exhibited rouleaux smear is used and the indistinctness of rings is noted. It is then observed under a microscope. Finally the ground-glass plate is calibrated in terms of the diameter of the corpuscles. This experiment provides a direct application in the field of medicine without sacrificing the rigors of theory or manipulation of the usual laboratory experiment using the ruled diffraction grating.

16. The Production of a Variable Low Frequency Alternating Voltage and Its Application to the Study of Transient and Steady State Phenomena. Lloyd W. Morris, *Louisiana State University, University, La.*—An easily constructed generator of simple harmonic motion is made by stretching casting line around four light pulleys at each corner of a long rectangle. If the midpoint of one long side is driven by a short crank, the midpoint of the other side is sensitive only to longitudinal motions of the crank since its sidewise motion produces only increased tension. When driven by a motor at constant speed, this gives a displacement that is closely harmonic. As the reciprocating parts consist only of the pulleys and line, the device may be operated at comparatively high speeds. If a short length of slide wire be inserted in the middle of the side opposite the crank and a steady current sent through it by light flexible leads, a sinusoidal voltage will exist between a fixed brush bearing on the slide wire and the midpoint of a potentiometer across the leads. The device thus becomes an inverter producing an alternating voltage of good wave form with a frequency from 1/4 to 10 or more cycles/sec. If this voltage be applied to a galvanometer and its displacement recorded photographically, it will serve to demonstrate the transient and steady state phenomena associated with an oscillatory system of variable damping when excited by a sinusoidal force of varying frequency. By means of a shutter cutting the light beam the relative phase of the driving force and the displacement may be recorded, and it is then possible to compare the phase angle, the steady state amplitude, and the frequency of the initial beats with their theoretically predicted values. Curves are shown for various types of excitation and response.

17. Three Demonstration Experiments on Rotatory Motion. Richard M. Sutton, *Haverford College, Haverford, Pa.*—(1) *Circular motion under constant central force.* A simple arrangement consisting of a mass M and a smaller

mass m (e.g., a wooden ball) connected by a cord passing through a glass or metal tube is set into operation by holding the tube vertically in one hand and causing the ball to describe a horizontal circular path while the mass M hangs downward on the axis. The ball swings at radius r such that $m\omega^2 r = Mg$, as may be checked to approximately 1 percent. Either the mass of ball or of suspended weight may be varied, of course, and the radius of rotation may be changed by swinging the ball at any desired speed. Strictly, the motion is that of a conical pendulum of period $2\pi(ml/Mg)^{\frac{1}{2}}$ where l is the length of cord from axis to rotating ball. (2) *Illustration of motion on a banked curve.* A glass funnel is mounted rigidly with axis vertical. A steel ball is set into motion in a horizontal plane within it at such speed that it is in dynamic equilibrium. As the ball is retarded by friction it spirals slowly to lower levels where the radius of revolution is smaller. Its angular speed increases while its linear speed decreases, as it must under constant central force. The ball may take as long as 20 sec. to settle to the bottom of the funnel only 10 cm below the point from which it starts. If its orbit is not horizontal, the ball describes an ellipse with varying angular speed not unlike planetary motion. A further, interesting example is shown for the case of a cone with axis horizontal; the steel ball is shot tangentially inward at the wide end in a direction making a small angle with an element of the cone. It emerges from the *same end* instead of from the mouthpiece toward which it was shot. The apparatus offers instructive analysis of force vectors. A ball thrown more or less at random into a large megaphone illustrates this latter case. (3) *The winning ball.* It is a familiar problem to determine the accelerations of rolling hoops, cylinders, and spheres (both hollow and solid) down a given inclined plane. Of these, the solid sphere has the largest acceleration, namely $5g \sin \theta/7$. What will roll faster? A ball or cylinder full of mercury! The mercury does not at first partake of the rotation and hence a larger fraction of the kinetic energy is translational than would be the case if the object were solid. Two or three amusing variants are shown. A cylinder for holding mercury may be made from wood or steel, or the mercury may be sealed inside a glass test tube fitting closely in a brass tube.

18. Demonstrating With Animations. Robert L. Petry, *University of the South, Sewanee, Tenn.*—Commercially-produced films have been examined in order to find animations that have special value for use as loops. The examples shown provide convenient demonstrations of difficult subject matter, the loops permitting the subject to be viewed as long at one time as may be desired. One demonstration shows an animation of the four strokes of a gas engine cycle, with spark plugs, valves, and valve cams in action; this is of special interest because several copies of this 5-ft. loop probably will be made available for general distribution by the firm that produced it. A second example deals with thermionic emission, effect of the grid in the three-electrode tube, and the use of tubes in general in transmitting and receiving circuits; also telephone transmitters and receivers, and electromagnetic coupling between circuits.

19. Colored Motion Photomicrography of the Formation of Crystals in Polarized Light. Kent. H. Bracewell, *Hamline University, St. Paul. Minn.*—A presentation of the film described in Am. Phys. Teacher **5**, 226 (1937).

20. A Semi-Automatic Film-Slide Projector. John A. Eldridge, *University of Iowa, Iowa City, Ia.*—This device enables the student or visitor to witness a self-administered lantern lecture. Two film-slide projectors operating in parallel project picture and text upon adjacent translucent screens. The observer changes the views by turning a knob. A suitable relay circuit extinguishes the lamps when they are not in use. With the wealth of illustrative material available to physics, the subject can be enlivened by concrete examples of physics in use.

Attendance

The registration of those in attendance lists 149 members of the Association and 35 non-members. Members who registered were:

R. B. Abbott, Purdue University; L. M. Alexander, University of Cincinnati; A. Antonakos, Appalachian State Teachers College; P. D. Bales, Howard College; I. A. Balinkin, University of Cincinnati; E. F. Barker, University of Michigan; N. F. Beardsley, University of Chicago; P. Bender, Goshen College; C. E. Bennett, University of Maine; C. A. Benz, Hammond (Ind.) High School; J. G. Black, Morehead State Teachers College; L. I. Bockstahler, Northwestern University; H. J. Bolger, University of Notre Dame; J. W. Buchta, University of Minnesota; B. Carpenter, Amherst College; T. J. Carroll, College of New Rochelle; C. W. Chapman, Michigan State College; Sister M. Rita Clare, College of St. Francis; F. F. Cleveland, Lynchburg College; E. H. Collins, Parsons College; F. W. Cooke, Illinois College; T. D. Cope, University of Pennsylvania; D. W. Cornelius, University of Chattanooga; E. F. Cox, Colgate University; H. Crew, Northwestern University; A. W. Dicus, Tennessee Polytechnic Institute; H. L. Dodge, University of Oklahoma; L. A. DuBridge, University of Rochester; R. T. Dufford, University of Missouri; J. R. Dunning, Columbia University; V. E. Eaton, Wesleyan University; R. L. Edwards, Miami University; J. A. Eldridge, University of Iowa; W. H. Eller, Western Illinois State Teachers College; D. S. Elliott, Tulane University; A. L. Foley, Indiana University; G. Forman, Western State Teachers College; A. Willena Foster, University of Western Ontario; C. R. Fountain, Peabody College; O. R. Fouts, University of Akron; O. G. Fryer, Drury College; H. Q. Fuller, University of Illinois; J. T. Gallahue, Welch Mfg. Co.; C. McC. Gordon, Lafayette College; R. C. Gowdy, University of Cincinnati; W. H. Gran, Western College; G. E. Grantham, Cornell University; L. B. Ham, University of Arkansas; W. J. Hamm, Maryhurst Normal School; J. P. Harper, St. Thomas College; D. L. Harmon, St. Mary-of-the-Woods College; R. E. Harris, Lake Forest College; J. Harty, Cape Girardeau (Mo.) Teachers College; R. J. Havighurst, General Education Board; H. C. Hazel, Indiana University; C. Hire, Murray State Teachers College; J. W. Hornbeck, Kalamazoo College; G. W. Horton, Wabash College; F. F. Householder, University of Akron; A. D. Hummell, Eastern Kentucky State Teachers College; E. Hutchisson, University of Pittsburgh; L. R. Ingersoll, University of Wisconsin; E. H. Johnson, Kenyon College; Vivian A. Johnson, Purdue University; J. M. Kelley, Loyola High School, Baltimore, Md.; W. L. Kennon, University of Mississippi; P. E. Klopsteg, Central Scientific Co.; H. V. Knorr, Antioch College; E. J. Kolkmeyer, Georgetown University; O. T. Koppius, University of Kentucky; C. J. Lapp, University of Iowa; K. Lark-Horovitz, Purdue University; G. Q. Lefler, Kent State University; R. W. Lefler, LaSalle-Peru-Oglesby Junior College; H. B. Lemon, University of Chicago; H. W. LeSourd, Milton Academy; O. E. McClure, Athens, O.; Louise S. McDowell, Wellesley College; J. F. Mockell, Indiana State Teachers College; J. A. Madigan, College of St. Thomas; K. V. Manning, University of Wichita; H. H. Marvin, University of Nebraska; J. A. Mescher, DeSales College; W. H. Michener, Carnegie Institute of

Technology; C. W. Miller, Michigan State College; R. Beatrice Miller, Overbrook High School, Philadelphia, Pa.; R. D. Miller, Iowa State College; J. G. Moorhead, Westminster College; L. W. Morris, Louisiana State University; W. W. Mutch, Pennsylvania College for Women; J. R. Nielsen, University of Oklahoma; R. T. O'Connor, Loyola University; C. J. Overbeck, Northwestern University; G. E. Owen, Antioch College; R. R. Palmer, Millikin University; G. T. Pelsor, University of Oklahoma; J. T. Peters, Overbrook High School, Philadelphia, Pa.; R. L. Petry, University of the South; C. J. Pietenpol, Washington and Jefferson College; W. B. Pietenpol, University of Colorado; J. G. Potter, Armour Institute of Technology; O. W. Railsback, Eastern Illinois State Teachers College; R. R. Ramsey, Indiana University; F. K. Richtmyer, Cornell University; E. Ritchie, Shurtleff College; D. Roller, Hunter College; H. H. Roseberry, Ohio University; T. S. Rowland, Northeast High School, Philadelphia, Pa.; R. A. Sawyer, University of Michigan; H. K. Schilling, Union College; A. R. Schmitt, Loyola University; R. S. Shaw, College of the City of New York; J. E. Shrader, Drexel Institute; W. E. Singer, Bowling Green State University; S. M. Skinner, University of Chicago; F. G. Slack, Vanderbilt University; A. W. Smith, Ohio State University; C. R. Smith, Aurora College; J. E. Smith, New Mexico Military Institute; L. E. Smith, Denison University; O. H. Smith, DePauw University; J. C. Stearns, University of Denver; R. J. Stephenson, University of Chicago; R. M. Sutton, Haverford College; V. F. Swaim, Bradley Polytechnic Institute; C. L. Swisher, North Dakota State College; L. W. Taylor, Oberlin College; J. L. Thompson, Emmanuel Missionary College; J. Todd, University of Kentucky; F. G. Tucker, Oberlin College; O. Tugman, University of Utah; J. Valasek, University of Minnesota; G. D. Van Dyke, Earlham College; G. A. Van Lear, Jr., University of Oklahoma; F. L. Verwiebe, Eastern Illinois State Teachers College; G. W. Warner, Wilson College; I. Walerstein, Purdue University; L. R. Weber, Friends University; D. L. Webster, Stanford University; N. E. Wheeler, Colby College; M. L. White, Pennsylvania State College; C. A. Whitmer, University of Oklahoma; Frances G. Wick, Vassar College; R. M. Woods, Northwestern University; A. G. Worthing, University of Pittsburgh; Charlotte Zimmerschied, Southern Illinois State Teachers College; E. H. Hall, Harvard University; G. W. Giddings, De Pauw University; M. J. Martin, University of Wisconsin; C. S. Morris, Manchester College.

The following non-members registered:

S. Atchison, K. H. Bracewell, J. H. Brayton, R. Caston, F. W. Crawford, J. M. Crawford, S. H. Dwight, S. W. Eager, H. V. Eagleson, J. E. Edwards, S. E. Elliott, Sister M. Flavia, Mrs. A. L. Foley, W. E. Forsythe, Cleota Fry, R. C. Grubbs, T. M. Hahn, P. P. Hegner, Sister M. Hortense, R. E. Howe, M. E. Hufford, C. E. Kuonen, E. C. McCracken, Madeline M. Mitchell, R. M. Morrow, Mrs. R. L. Petry, J. F. Price, J. B. Rose, O. E. Rumple, E. W. Skinner, W. C. Smith, O. L. Snow, Sister Mary Therese, P. K. Weimer, A. F. Morris.

Annual Report of the Treasurer

Balance brought forward from Dec. 15, 1936	$1233.00

CASH RECEIVED

Dues received [1] for 1937	$2445.00	
Dues received for 1936	63.00	
Dues received for 1938	166.00	
Exchange charge paid	1.70	
Donations	411.50	
Total Cash Received	$3087.20	
Total deposited from 12/15/36 to 12/15/37	3087.20	
Total cash available		$4320.20

DISBURSEMENTS

Postage and supplies	$ 144.03	
Printing	65.22	
Secretary, Editor's office	190.00	
Secretary's office expense	95.20	
Editor's traveling expense	9.00	
Membership campaign, 1936	30.00	
Payments to American Institute of Physics	1903.12	
Returned check	3.00	
Discount charge	1.05	
Total disbursed		2440.62
Balance on hand [2] Dec. 15, 1937		$1879.58

PAUL E. KLOPSTEG, *Treasurer*

I have audited the books of account and records of Dr. P. E. Klopsteg, Treasurer of the American Association of Physics Teachers, for the year ended December 15, 1937, and hereby certify that the foregoing statement of receipts and disbursements correctly reflects the information contained in the books of account. Receipts during the year were satisfactorily reconciled with deposits as shown on the bank statements and all disbursements have been satisfactorily supported by vouchers or other documentary evidence.

WILLIAM J. LUBY, *C. P. A.*

Chicago, Illinois,
December 24, 1937.

[1] On December 15 there were 862 members in good standing.

[2] A balance of approximately $1750 is due the American Institute of Physics for the publication of the journal during 1937.

Report of the Secretary

The executive committee of the American Association of Physics Teachers held three meetings at Indianapolis. Members present were F. K. Richtmyer, H. B. Lemon, T. D. Cope, P. E. Klopsteg, J. G. Black, D. Roller, A. W. Smith, L. W. Taylor, G. W. Warner, D. L. Webster, and A. G. Worthing. D. S. Elliott, W. H. Michener, and R. M. Sutton were present at some of the meetings by invitation.

Chairmen of special committees of the Association were appointed for 1938 as follows: Physics in relation to medical education, W. E. Chamberlain; Manual of demonstration experiments, R. M. Sutton; Tests and testing, C. J. Lapp; Training of physicists for industry, P. I. Wold; Terminology, symbols and abbreviations, D. Roller and H. K. Hughes; Physics in secondary education, A. W. Smith; Sources of revenue, A. G. Worthing; Nominating committee, J. C. Hubbard.

Upon the recommendation of the Editor, V. L. Lenzen, L. W. McKeehan, and O. M. Stewart were appointed associate editors of *The American Physics Teacher* for a period of three years.

F. K. Richtmyer was appointed representative of the Association on the governing board of the American Institute of Physics to succeed P. E. Klopsteg, whose term has expired. To a request from the Institute of Physics for advice on the question of holding a second joint meeting of the Founder Societies, the secretary was directed to reply that the proposal is regarded with favor, and that a

day's session on "The Place of Physics in General Education" is recommended.

J. G. Black, G. W. Warner, and A. G. Worthing, representatives of the Kentucky, Chicago, and Western Pennsylvania chapters, respectively, gave brief accounts of the activities of their chapters during 1937.

The Annual Business Meeting. The annual business meeting was held at 12:00 noon, December 29, in the Indianapolis Athletic Club. President Richtmyer presided. The results of the election of officers for 1938 were announced as follows:

President: F. K. Richtmyer.

Vice President: H. B. Lemon.

Members of the Executive Committee: D. S. Elliott, A. A. Knowlton.

President Richtmyer announced that one of the foundations has made a grant to the Association to aid in the further development of *The American Physics Teacher.* A motion was made and prevailed that the domestic, non-member subscription rate to *The American Physics Teacher* be made $5.00, and the foreign non-member rate, $5.50; and that the executive committee be authorized to determine rates for non-members in the future.

It was voted that, at the discretion of the committee on awards for notable contributions to the teaching of physics, the award shall carry with it honorary membership in the Association.

Brief reports and remarks were made by D. Roller, on the work of the journal; by P. E. Klopsteg, the treasurer; by H. L. Dodge, on the work of the membership committee; by R. M. Sutton, on the manual of demonstration experiments, and the prospective tour of European physics laboratories; and by G. A. Van Lear, Jr., on suggested symposiums and committees.

By unanimous vote, the Indiana committee of the Association was thanked for its services in making arrangements for the meeting; its membership was S. E. Elliott, G. W. Horton, E. P. Miller, R. R. Ramsay, and O. H. Smith, *Chairman.*

THOMAS D. COPE, *Secretary*

Available Industrial Fellowships

Central Scientific Company Undergraduate Industrial Fellowships. To assist in the program sponsored by the American Institute of Physics and the American Association of Physics Teachers, designed to emphasize training in industrial physics, the Central Scientific Company offers two industrial fellowships which will be awarded on the following basis: (1) Tenure, July 1, 1938 to June 30, 1939; (2) Stipend, $1200; (3) Applicants should be candidates for the Bachelor's degree in June, 1938, with a major in physics and strong minors in mathematics and chemistry; (4) Preliminary selection will be based on scholastic standing, recommendations and replies to questionaries, and final selection will be made by examinations and interviews; (5) The major professor of successful candidates will be expected to lend every assistance in helping the fellows secure positions at the end of the fellowship period. The fellows will be under the supervision of the Department of Research and Development, but will be given an opportunity to gain experience also in other departments of the Company. For application blanks, address Dr. M. N. States, Central Scientific Co., 1700 Irving Park Blvd., Chicago, Ill. Appointments will be made about April 1.

Westinghouse Post-Doctorate Research Fellowships. To contribute to the development of the fundamental sciences on which modern industry is based and to enable a group of able investigators to become familiar with the scientific problems confronting the electrical industry, the Westinghouse Electric Manufacturing Company has established ten post-doctorate fellowships for research in physics, including chemical physics and physical metallurgy. The fellows will devote full time to their research projects at the Westinghouse Research Laboratories in East Pittsburgh. Their work will be under the general supervision of Dr. E. U. Condon, newly appointed associate director for the program of fundamental research. The stipend is $2400 a year. Application must be made before March 1, on a form which may be obtained from the Manager, Technical Employment and Training Dept., Union Bank Bldg., Pittsburgh, Pa.

Appointment Service

REPRESENTATIVES of departments or of institutions having vacancies are urged to write to the Editor, Columbia University, for additional information concerning the physicists whose announcements appear here or in previous issues. *The existence of a vacancy will not be divulged to anyone without the permission of the institution concerned.*

20. Ph.D. Univ. of Minnesota; S.B., S.M., M. I. T.; 1 yr. grad. work, Univ. of Iowa. Age 38, married, 2 children. 17 yr. teaching experience in universities, colleges and technical schools, including 10 yr. head of department. Interested in progressive undergraduate and graduate teaching and research, including mathematical physics.

21. M.S. Kansas State. Age 38, married, 2 children. Research, acoustics. Experienced in laboratory maintenance, design and construction of apparatus, and writing of manuals. Desire teaching or industrial laboratory employment.

22. Ph.D. Univ. of Illinois; A.B. Wabash College. Age 31, married, 2 children. Has taught 4 yr. in liberal arts college and 1 yr. in large state university. Co-author, laboratory manual. Interested in college or university teaching, laboratory development, and research. Available, fall 1938.

Departments having vacancies or industrial concerns needing the services of a physicist are invited to publish announcements of their wants; there is no charge for this service.

RECENT PUBLICATIONS AND TEACHING AIDS

Intermediate and Advanced Textbooks

Weather Elements. Thomas A. Blair. 400 p., 107 fig., 16×23 cm. *Prentice-Hall*, $4. Professor Blair's book is a distinct contribution to the field of college textbooks· meteorology has had several serviceable books but elementary meteorology was particularly in need of a shift in emphases and extension. Most previous textbooks have had the tendency to over-emphasize one of the two aspects of meteorology: the geological aspect, world climate and its effect on man; and the physical aspect, the why and wherefore of the behavior of the weather elements. *Weather Elements* maintains a judicious balance; the author has chosen his material carefully, selecting the important and useful, and has not become verbose or too abstruse for college students. Paradoxically, the book is surprisingly nonmathematical and thoroughly physical. A first course in physics is an adequate prerequisite.

Although the theory of air mass analysis is now well out of the embryonic stage and has been definitely established as a powerful tool in weather prognostication, heretofore this theory was best studied in the original publications. In the present book we now have a brief but good introduction to the subject. The idea of conservative elements is discussed, and definitions of these elements are clearly and accurately stated and explained.

Outstanding features of the book are the list of workable problems, the excellent bibliography, a useful set of tables, and the chapter on the functions of the U. S. Weather Bureau. More colleges should find it feasible to offer a 2- or 3-hour course in meteorology with this adequate text, and most science departments will find it a valuable general reference.—Arthur G. Rouse, *St. Louis University.*

Electricity and Magnetism. A. W. Hirst, chief lecturer in electrical engineering, College of Technology, Leicester. 338 p., 201 fig., 5 tables, 15×23 cm. *Prentice-Hall*, $4.50.

Electricity and Magnetism. S. Leroy Brown, professor of physics, University of Texas. 310 p., 126 fig., 10 tables, 14×22 cm. *Holt*, $2.80.

Electricity and Magnetism, An Introduction to the Mathematical Theory. H. S. Ramsey, Cambridge University. 267 p., 147 fig., 14×22 cm. *Cambridge Univ. Press*, $3.25.

Electricity and Magnetism. S. G. Starling. Ed. 6. 630 p., 446 fig., 23 tables, 15×22 cm. *Longmans, Green*, $4.00.

Mr. Hirst's excellent introduction to the subject of electricity and magnetism is presumably intended for electrical engineering students but should be equally suitable for other students with a prerequisite of a general course in physics. The orderly and logical development of the material is particularly worthy of mention; it reflects careful planning on the part of the author and an understanding of students' needs. For example, after a review of units and mechanical principles, the student is given a broad view of the field through a preliminary discussion of the electrical structure of matter, the energy changes involved in the production and utilization of electrical energy, and the various effects of an electric current. It is to be regretted, however, that a more detailed treatment of alternating current circuits is not included; the effects of inductance and capacitance are pointed out qualitatively, yet no quantitative results are given. Furthermore, a chapter on vacuum tubes would have made this otherwise commendable text more complete. The book's usefulness is enhanced by the inclusion of a large number of solved, illustrative problems.

In writing his text, presumably designed for a course to follow general physics, *Professor Brown* has attempted to stimulate the interests of students in a more comprehensive consideration of electricity and magnetism by treating first those subjects that will utilize their general information. This would seem to be an excellent method of approach for an elementary survey course but it seems questionable whether it is necessary or advisable for students who are taking a specialized course and who need a logical development of the subject. The text is very concise, about 100 pages being given to problems, a list of experiments, and review assignments, and it seems as though the students deserve a more complete discussion of details. A most commendable feature of the book is the fine choice of more than 175 problems.

Professor Ramsey states that his text was written to fill "the needs of candidates for Part I of the Mathematical Tripos." The choice of material is thus limited. Slightly more than half the book is devoted to the classical theory of electrostatics, smaller portions to electric currents, magnetism and electromagnetism, and about 30 pages to induced magnetism and electromagnetic induction. Being an introductory text to the mathematical theory, it gives little space to practical applications and apparatus. A distinctive feature is the inclusion of a considerable number of solved problems in addition to the more than 300 unsolved ones, most of which are taken from English university examination papers. Unlike most books of its kind, the theory of electrostatics is developed from Gauss' theorem rather than from Coulomb's law. There is no discussion of the modern theory of dielectrics and dielectric polarization. Because of the aforementioned limitations in content, this book may be recommended for supplementary reading only, as its suitability as a text in most American courses is questionable.

There are few American physicists who have not at some time used *Starling* as a text or reference. Its success is attested to by the appearance of a sixth edition. In the

present edition, brief discussions of most of the modern developments have been added. In the chapter on electrostatics, the neutron and positron are mentioned and the modern conception of dielectrics and dielectric polarization pictured. Other new sections relate to Kapitza's work with strong magnetic fields, the Heaviside and Appleton layers, electron optics, deuterium, cosmic rays, superconductivity, induced radioactivity, and artificial disintegration. Several tables and the section on electric and magnetic units have been revised. The Curie-Weiss law and the Weiss theory of magnetism are included and sections on the Hall effect and allied phenomena, omitted from some of the editions, have been reintroduced. In short, the new, revised Starling should prove even more useful than its predecessors.—H. N. OTIS, *Hunter College.*

Experimental Radio. R. R. RAMSEY, professor of physics, Indiana University. Ed. 4. 210 p., 167 fig., 15×23 cm. *Ramsey Publishing Co.* (Bloomington, Ind.), $2.75. This is the fourth edition of a pioneer laboratory manual on all phases of high frequency measurements, for students who have had first-year college physics. Since rectified alternating current is now generally used in radio sets, the present edition has been revised so that power supplies can be used in most of the 132 experiments. The manual is a companion volume to the same author's *The Fundamentals of Radio* [Am. Phys. Teacher **4**, 46 (1936)].

REFERENCE BOOKS FOR FIRST COURSES

Science and Music. SIR JAMES JEANS. 268 p., 64 fig., 14×21 cm. *Macmillan*, $2.75. A nonmathematical but important and serious account of the physics of music, including the mechanisms of orchestral instruments and the acoustics of concert halls. The author is not only a master of exposition, but evidently is at home both with his purely musical material and with the modern work on sound. Among the main topics discussed are tuning forks and pure tones, vibrations of strings and harmonics, air vibrations, harmony and discord, the concert room and hearing. The book contains a number of small errors and loose statements, some of which have been introduced apparently with the intention of simplifying the treatment. The book work is excellent.

The Advancing Front of Science. GEORGE W. GRAY. 364 p., 15×22 cm. *Whittlesey House, McGraw-Hill*, $3. Here, at last, is the author of a popular treatment of nuclear problems who spends his time on the fundamental work of Tuve and Hafstad and on the theoretical interpretation of that work without entering into rhapsodies on the possibilities, real and imagined, of artificial radioactivity and transmutation, and yet manages to present a readable and interesting chapter on nuclei.

Mr. Gray opens his discussion with the statement of Dirac that the fundamental problems before physics are the relativistic formulation of the quantum theory, the nature of the nucleus, and the nature of life. From this springboard he leaps into the sea of evidence which the physical and biological sciences have charted in their search for the solution of these problems. Unlike many popular authors, he seldom wanders into the depths of speculation, and in staying near the beach of experiment he at least has the advantage of keeping his feet on solid ground but at the same time of allowing his reader to feel the impact of the surf.

It is not only in his treatment of nuclear physics that the author shows an admirable restraint combined with an exceptional clarity, for he handles the other sections of physics upon which he touches—the red shift, architectural acoustics, the Kennelly-Heaviside layer and cosmic rays—in a similar manner. Perhaps the very fact that Mr. Gray is not a working scientist makes him the more able to choose the essentials of each subject and to present them in a way that the layman can understand.

Probably the parts of the book which will most interest the physicist are those in which the application of physical and chemical methods to the fields of biology and psychology are discussed. Here are lively, human and interesting accounts of the work of Stanley and his collaborators on the viruses, of that of Loomis, Hobart and Harvey on brain waves, and of many other fields. I leave the question of the accuracy of his treatment to those better qualified to judge, but his handling of physical problems gives me faith in the rest of the book.

The volume is not, of course, without its slight inaccuracies or its statements that may lead to false impressions. But the errors are minor and in such a remarkable piece of exposition should be overlooked. The book will be read with pleasure by the teacher of physics, may be presented to his students with an assurance of their profit, and will be enjoyed and understood by his lay friends.—WALTER C. MICHELS, *Bryn Mawr College.*

BOOKS FOR SECONDARY SCHOOLS

High School Teachers' Methods. CHARLES ELMER HOLLEY, formerly head of the department of education, James Millikin University. 521 p., 14×21 cm. *Garrard Press* (Champaign, Ill.), $3. A textbook for an educational methods course.

Elementary Photography. C. B. NEBLETTE AND FREDERICK W. BREHM, department of photographic technology, Rochester Athenaeum and Mechanics Institute; AND EVERETT L. PRIEST, Rensselaer Falls (N. Y.) High School. 261 p., 130 fig., 22 tables, 14×20 cm. *Macmillan*, 72 cts. An excellent, carefully planned manual for the use of junior and senior high school students who have not had physics and chemistry. Quite comprehensive, well-planned and illustrated, and certainly worth the price asked for it.

Electrical Occupations for Boys. LEE M. KLINEFELTER. 227 p., 67 photographs, 13×19 cm. *Dutton*, $2. This survey by an electrical engineer of vocational opportunities in the electrical field should be of especial help and encouragement to boys who may not have the advantage of a college education. Employing a narrative style in order to hold the interest of the youthful reader, the

author relates the experiences of a boy and his father who visit different electrical centers and obtain information on the requirements, advantages, salaries, chances of promotion, etc., for such occupations as power plant manager, electrical wirer, battery man, radio operator, army and navy specialists, etc.

Science Training for Metal and Wood Trades. WILLIAM H. DOOLEY, Straubenmuller Textile High School, New York City. 575 p., 267 fig., 17 tables, 13×20 cm. *Ronald Press Co.*, $2.40. This book, a revised edition of the author's *Applied Science for Metal and Wood Workers* (1919), is intended for students who do not take the traditional school courses in physics, chemistry, or biology, but who can profit by a study of the scientific principles underlying the fundamental trades. Of the 44 chapters, about half are devoted to basic physics, four deal with chemistry, and the remainder discuss such subjects as hand-tools, boilers, gas engines, methods of heating, iron and iron molding, pattern-making, machine-shop practice, paints and varnishes, lumber, and wood-working machines.

POPULAR BOOKS

Astronomy for the Millions. G. VAN DEN BERGH. Tr. from the Dutch by Joan C. H. Marshall and Th. de Vrijer. 383 p., 40 fig., 14×21 cm. *Dutton*, $3.50. An entertaining and informative popular account of many of the phenomena and the main theories of astronomy.

The World of Atoms. ARTHUR HAAS, professor of physics, University of Notre Dame. Tr. by George B. Welch, Northeastern University. 197 p., 54 fig., 15×23 cm. *Van Nostrand*, $3. A newly translated, revised and enlarged edition of twelve nonmathematical lectures for the serious lay reader. The first English edition appeared in 1926.

The Story of Science. DAVID DIETZ, lecturer in general science, Western Reserve University, and science editor of the Scripps-Howard Newspapers. Ed. 4. 405 p., 47 plates and figs., 15×22 cm. *Dodd, Mead*, $3.50. A revised edition of an unusually comprehensive and expertly written, popular account of modern, natural science. About three-fourths of the book is devoted to the physical sciences.

The Story of Tunnels. ARCHIBALD BLACK. 260 p., 46 photographs, 15×23 cm. *Whittlesey House, McGraw-Hill*, $2.75. An excellent nontechnical account of the building of tunnels of all types, including subway systems, and various great railroad, water-supply, highway, and irrigation tunnels, by the author of *The Story of Bridges* [Am. Phys. Teacher **5**, 143 (1937)]. The book is said to be the first modern history of tunnel building, of any kind.

MISCELLANEOUS BOOKS

Mechanical Refrigeration and Service. ADRIAN J. SNYDER, chief refrigeration engineer of Murphy & Snyder. 157 p., 35 fig., 15×23 cm. *Louellen Pub. Co.* (39 Union Square W., New York), $2. An account for laymen of the theory and applications of refrigeration, and of the construction and servicing of the various types of mechanical refrigerators now on the market.

Zero to Eighty. AKAD PSEUDOMAN (E. F. Northrup). 295 p., 29 fig., 15×23 cm. *Scientific Publishing Co.* (Princeton, N. J.), $3. The imaginary adventures of an inventor living in 2000 A.D. who circumnavigates the moon in a projectile ship. The projectile is steered by means of rockets and acquires its momentum by eddy-current thrust in a specially designed coil excited by 3-phase current. Although it is of the Jules Verne type, the book is most likely to interest the reader who is able to follow the technical argument.

The World and Man. Ed. by FOREST RAY MOULTON. 533 p., 173 fig., 15×23 cm. *Univ. of Chicago Press*, $3. This authoritative text for an introductory, general science, orientation course is the successor to *The Nature of the World and Man* (1929). Intended to cover the advances made in the physical and biological sciences during the last decade, it devotes a chapter to each of ten major fields. The chapter on physics was prepared by H. B. Lemon and R. J. Stephenson. It occupies 47 pages and is entitled "Particles and Waves," the main topics discussed being electricity, wave motion, and aspects of recent physical theory. No questions or exercises are included in the book.

Handbook of Chemistry. Edited by NORBERT ADOLPH LANGE, lecturer in organic chemistry, Cleveland College of Western Reserve University. Ed. 2. 1802 p., 13×20 cm. *Handbook Publishers* (Sandusky, O.), $3. Although this handbook of chemical and physical constants was prepared for the use of industrial chemists, it will also prove useful to students of physics and engineering. The present enlarged edition contains numerous new and revised tables. The 250-page section of mathematical tables and formulas was prepared by R. S. Burington, assistant professor of mathematics, Case School of Applied Science. The unusually complete index involves some 2700 entries. Excellent typography.

LANTERN SLIDES

General Electric Illustrated Lectures. *General Electric Co., Visual Instruction Sec., Publicity Dept.* (Schenectady, N. Y.), gratis except for transportation costs. The following lectures, illustrated by glass or film slides, are available:

Street lighting. Brief history of street lighting; street lighting, advantages and statistics; modern street lighting luminaires; the application of modern street lighting.

Floodlighting. Possibilities of floodlighting for commercial advertising, decorative effects, and places of amusement; various applications of floodlighting.

Charles P. Steinmetz. Biographical.

Within the gates of General Electric. Interesting facts about the General Electric Co., the amount and types of apparatus manufactured; pictures are shown of original factory units, some of the newer buildings and many applications of electric apparatus.

Thomas A. Edison. Biographical.

History of the General Electric Co. Pictures the work of various electric-light pioneers whose work and systems have survived, and of the men who have contributed to the development of the General Electric Co., with descriptions of the individual work of each.

The all-electric ship. A complete description of electric ship propulsion, and of the modern conveniences and furnishings of the modern all-electric ship.

Vacuum tubes. Theory of vacuum-tube operation, typical applications, line diagrams of electric circuits used in vacuum-tube installations, and manufacture, uses and possibilities of tubes for power purposes.

Heat. Theory of heat and its application to industrial and domestic purposes. Semi-technical and suited to to elementary physics and chemistry classes.

Magnetism. Elementary conceptions of magnetism, several phases of the subject that have to do with the molecular theory of magnetism, contributions of Faraday and Steinmetz, interrelation of electricity and magnetism, and the importance of hysteresis in the design of alternating-current apparatus.

Mechanics. An outline of what is comprised in the study and practice of mechanics, with clear definitions and illustrations of terms. Suited to secondary school classes.

The following lectures are available with film slides only:

A brief history of the electrical industry. The more important events and dates, with illustrations of early types of highly developed apparatus now in use.

History of floodlighting. Floodlighting applications, beginning with the initial electrical lighting of Niagara Falls and proceeding with other outstanding lighting of buildings, towers, bridges, statues, athletic fields, etc.

Some recent developments in the electrical industry. A review of the outstanding events and achievements in 1936.

Live longer with light. Highway lighting and its relation to accidents.

Manuscripts illustrated by glass slides may be borrowed for definite showing dates; those illustrated by film slides may be obtained on a permanent loan basis if desired.

Catalog of Picturols and Film Slides. 23 p., 10×23 cm. *Society for Visual Education* (327 S. La Salle St., Chicago), gratis. Lists many physical science subjects that can be purchased from various producers of film slides.

Suppliers of Slides on Science Subjects

C. W. Briggs Co., 338 S. 15 St., Philadelphia, Pa.

Brownell, 176 E. 32 St., Patterson, N. J.

Central Scientific Co., 1700 Irving Park Blvd., Chicago, Ill.

Conrade Slide and Projection Co., 709 E. 8 St., Superior, Wis.

Denoyer-Geppert Co., 5235 Ravenswood Ave., Chicago, Ill.

Division of Motion Pictures, Department of Interior, Washington, D. C.

William E. Dudley, 736 S. Wabash Ave., Chicago, Ill.

Fairchild Aerial Surveys, Inc., 224 E. 11 St., Los Angeles, Cal.

General Electric Co., Motion Picture Div., Schenectady, N. Y.

General Film, Inc., 156 King St., W., Toronto, Ontario, Canada.

Keystone View Co., Meadville, Pa.

McIntosh Lantern and Slide Service, 30 E. Randolph St., Chicago, Ill.

National Studios, Inc., 226 W. 56 St., New York, N. Y.

Henry G. Peabody, P. O. Box 111, Pasadena, Cal.

Victor Animatograph Co., Davenport, Iowa.

W. M. Welsh Scientific Co., 1515 Sedgwick St., Chicago, Ill.

Williams, Brown and Earle, Inc., 918 Chestnut St., Philadelphia, Pa.

Suppliers of Lantern Slide Materials

Eastman Kodak Co., Rochester, N. Y. Photographic materials and instructions.

Keystone View Co., Meadville, Pa. Ink crayon, typewriter, silhouette.

Radio-Mat Slide Co., 1819 Broadway, New York, N. Y. Typewriter.

J. C. Reiss, 10 Hill St., Newark, N. J. Ink, crayon, typewriter, silhouette.

Motion Picture Films

Ford Rouge Plant. 16 or 35 mm. sound film, 30 min. *Ford Motor Co.* (Dearborn, Mich.), loaned gratis. A complete tour of the Ford Rouge plant, with narration by Lowell Thomas.

Modern Magic in Fire Protection. 16 mm. sound film, 29 min. *Rockwood Sprinkler Co.* (38 Harlow St., Worcester, Mass.), loaned gratis. Shows automatic action of sprinklers and of various auxiliary devices for controlling doors, windows, water curtains, etc., on the outbreak of fire.

Pamphlets and Trade Literature

The Miracle of Ice from Heat. 27 p., 29 figs., 22×28 cm. *Servel, Inc.* (51 E. 42 St., New York City), gratis. Well-planned descriptions, both simple and technical, of the principle and operation of the Electrolux "gas" refrigerator. Excellent diagrams.

Theatrical Lighting and Effects. Catalog F. 32 p., 95 figs., 28 × 21 cm. *Display Stage Lighting Co.* (442 W. 45 St., New York City), gratis. Catalog of a modern theatrical and display lighting equipment.

Holophane Lighting Equipment. *Holophane Co.* (342 Madison Ave., New York City), gratis. Various illustrated publications which show the control of room illumination through prismatic action.

Principles of Permanent Magnet Movable Coil and Movable Core Iron Types of Instruments. Monograph B-7. 95 p., 58 figs., 15 × 23 cm. *Weston Electrical Instrument Corp.* (Newark, N. J.), gratis to teachers. A valuable booklet, prepared especially for the use of teachers and students of elementary physics; 22 laboratory experiments are described that demonstrate the general circuit con-

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nections and the underlying principles in electrical measurements.

Weather Instruments and the Weather. *Taylor Instruments Companies* (Rochester, N. Y.). Each of the following popularly written booklets in the Taylor "Weather Series for the Amateur," by P. R. Jameson, is 15 × 20 cm and costs 15 cts. postpaid, stamps or silver:

Practical hints for weather forecasters. 32 p., 11 figs. Care and adjustment of barometers, temperature and the weather, scale of winds, forecasting with the barometer.

Humidity, its effects on our health and comfort. 24 p., 4 figs. On matters concerning the necessity for connecting inside moisture conditions, with hygrometer and dew point tables.

The mountains of cloudland and rainfall. 24 p., 7 figs. Rainfall measurement; varieties, speeds and elevations of clouds.

The thermometer and its family tree. 24 p., 16 figs. History and manufacture of thermometers.

The barometer as the foot rule of the air. 24 p., 10 figs. Invention and development of the barometer; correct method of using barometers to measure heights.

The compass, the signpost of the world. 24 p., 12 figs. History and use of the compass, with U. S. declination map.

The following leaflets, each 8×16 cm, are furnished gratis in reasonable quantities to teachers: "Facts about rainfall," "Temperature," "What is this thing called humidity?," "Taylor barometers," "A drop of mercury, a tube of glass," "Guides to health and comfort."

DIGEST OF PERIODICAL LITERATURE

Physics in Industry

Training of physicists for industry. Anon.; *J. Sci. Inst.* **14**, 392, Nov., 1937. In accordance with the scheme instituted last year in England to provide opportunities for physics students to gain first-hand experience in the applications of physics, various organizations were again invited to offer facilities for students to work in their laboratories during the vacation. As a result, 27 firms, 6 research associations, and 3 government establishments offered to provide such facilities, and several students availed themselves of the opportunities. The scheme has proved a marked success for everyone concerned; in fact this year requests were received for additional students to assist with special researches.

Physics in Medicine

Applying physics to medicine—Electrical fields around living organisms. C. T. Lane; *Yale Sci. Mag.* **11**, 4–5, 26–27, Winter, 1937. It is a truism that the collective efforts of several men are likely to be more productive of results than that of a lone individual, and this is especially true of medical science. Problems involving living things are so immensely complex that they must be attacked from many different sides; so enormous a variety of technics must be employed that no one person can be master of them all.

Since the building blocks of inanimate matter are mainly electrical particles, and the forces which hold atoms and molecules together are mostly electrical in character, we are naturally led to suspect that living matter should have associated with it similar electrical properties. That this is so, has long been known. Galvani's discovery of "animal electricity" has become a classic experiment alike for physics and medicine. Since his day innumerable experiments of an electrical character performed on living things have led to a whole new branch of medicine, *electro-medicine.*

It is a striking fact that living organisms possess an amazing constancy of form despite great differences in the environment in which they grow. For instance, a chicken embryo, despite the greatest differences in its physical environment, will invariably develop into the creature with a beak, feathers, wing, etc., that we call a chicken; and we shall never find a beak where a wing should be. The "pattern of organization" is invariable. Surely there must be some fundamental factor or "force" present in the original embryo which compels it to grow in this invariable way. This mysterious factor has been given a number of names, such as *entelechy.*

In 1932 H. S. Burr, an anatomist, advanced a hypothesis regarding entelechy which could be tested by direct experiment; he proposed that it was nothing more or less than an electric field. In 1935 the hypothesis was put on a much sounder basis by Burr and F. S. C. Northrop, a philosopher. Now the existence of these hypothetical electric fields should give rise to differences of electric potential between various parts of the living organism; furthermore, these should be steady-state potentials forming a definite spatial pattern with respect to that organism. The question thus arose of designing a suitable instrument to measure these potentials and the author, a physicist, attacked the problem.

Several peculiarities connected with electrical measurements on living systems should be mentioned. First, it is not permissible to draw appreciable current from the living system under test at any time, for even a few microamperes will polarize and thus destroy the delicate mem-

branes; this rules out such instruments as voltmeters and potentiometers. Again, since it is to be expected that the potential differences in, for instance, the embryos of small animals would be only a few millionths of a volt, high impedance instruments such as quadrant electrometers are ruled out because of their relative insensitivity. From these considerations alone—and others as well—it appeared that the vacuum tube amplifier of the electrometer type was the only practical solution of the problem. But one difficulty with it in biologic work is the matter of shielding; it would be difficult, for instance, to shield a hospital patient from disturbances due to the elevators in the building. Again, such a highly sensitive device involves inherent difficulties, the worst being the drift in the zero point, which would be fatal in observations extending over several hours. No instrument in fact appeared to satisfy all or even most of the requirements. Indeed, we could hardly expect instruments designed for purely physical measurements to fulfill the considerably different requirements of the biologist; the problem of measuring minute steady-state voltages rarely arises in physics.

The apparatus finally developed after more than a year of experimentation is to all outward appearances a double tube, bridge-type d.c. amplifier. Two vacuum tubes form respectively two of the four arms of a Wheatstone bridge, their respective plate resistors forming the remaining arms. When the galvanometer is set at zero by adjusting the plate resistor of one tube and a signal is then applied between grid and filament of one tube, the resistance of the tube changes and hence the galvanometer shows a steady deflection that is proportional to the applied signal. The light from the galvanometer mirror is focused on motion picture film and a graph of the potential variations of an organism with time recorded. This apparatus as finally evolved will detect differences of 5×10^{-6} v and emits a polarizing current of less than 10^{-12} amp. It shows practically no drift over a period of several hours and can be operated during storms and other severe electrical disturbances.

The instrument has been applied to an amazingly wide variety of problems by Burr and his colleagues. For example, its use in investigating the bioelectric properties of chick and salamander embryos brought to light the first evidence for the correctness of the Burr-Northrop theory. The chicken embryo was placed in a small dish of normal saline solution and was so small that the electrodes had to be applied to it under a microscope. An electric potential was found actually to exist in the surrounding liquid at such relatively large distances from the embryo as 2 mm, the decrease in voltage with distance being very exactly logarithmic. There is some reason to believe that an embryo behaves very much like an electric dipole. When the organism dies the voltages disappear. These experiments were placed beyond doubt by substituting for the living embryo an artificial body of known electric characteristics; this idea of checking with a "robot embryo" originated with L. Nims, a physical chemist who is working in physiology.

Another research of great interest was concerned with electrical studies of mice predisposed toward cancer. The electrodes were placed on the chest areas of the animals. The resulting potential-time graphs had one form that was typical for healthy mice, but quite another for mice that later developed cancer. Disturbances in the electrical pattern of the organism appeared on the graph some days before the developing cancer could be detected by any other known clinical methods.

Although our knowledge of the mechanism by which organisms produce these electric fields is very scanty, it seems reasonable to suppose that the individual body cells are the seat of the e.m.f.'s and that some force exists within the organism which tends to align the cells so that the individual potentials become additive. Since the potentials observed are often small it may of course be that certain groups of cells tend to oppose other groups, leaving only a small, resultant e.m.f.

History and Biography

Bicentenary of Galvani. Anon.; *Nature* 140, 391–2, Sept. 4, 1937. It was as an anatomist and physiologist, not as a physicist, that Luigi Galvani made his experiments on the muscular contractions of partly dissected frogs suspended by copper hooks from the iron rails on the balcony of his house. These experiments paved the way for the work of Volta, who was about eight years younger than Galvani. In awarding the Copley medal to Volta in 1794, Sir Joseph Banks said that Volta "has detected in the metals, which Dr. Galvani considered as mere agents in conducting his animal electricity, that very existing principle which the Doctor and his followers had overlooked." From a careful study of Galvani's writings, however, J. D. Forbes concluded that "the great value of Volta's paper, at the time, was undoubtedly that it directed the attention of English experimentalists to Galvani's discoveries. . . ."

Science Registrations in Schools

Registrations in Science. C. A. Jessen and L. B. Herlihy; *Sch. Life* 22, 314, 320, June 1937. Studies of registrations in secondary school subjects made by the U. S. Office of Education since 1890 show that the percentage of the total enrolment in natural science subjects has gradually decreased. Physics, physiography, and physiology were the leaders at first, but their supremacy has vanished as new science subjects have taken over much of their content and many of their registrants. Physics is the only one of the three that still has a large registration.

During the last 15 years general science has been the leader. In 1934 it was offered by 71 percent of the schools and taken by 15 percent of the students. Next came biology with 63 percent of the schools offering it and 12 percent of the total number of students registered for it. Physics was third and chemistry fourth in number of schools offering these subjects; but in registration, chemistry exceeded physics. These relative positions are the same which these four sciences occupied in 1928.

Of the total number of students enroled in the schools, 38.8 percent took one or another of these four sciences. Within the science registration itself, nearly two-fifths took

general science, less than one-third biology, one-sixth chemistry, and one-eighth was registered in physics. During the period 1928–34, biology made the greatest relative gains in number of schools offering it, with chemistry second. In registration gains biology and chemistry were close together. General science was third in percentage increases both in schools offering it and in students registered. Physics was definitely in fourth position in both particulars. In 1934, 8,466 schools offered physics, the physics enrolment being 282,820.

Noticeable variations appear among states in the emphasis placed upon the different science subjects. For example, the proportion of the total number of schools which offer physics varies from about 13 percent in Arkansas and Virginia to 75–80 percent in Iowa and Wisconsin. In physics registration, the variation between states is from about 2 to 11 percent. Certain states apparently have been more insistent on building up registrations throughout the science departments than have others. Moreover, some have developed high percentages of registration in one or more science subjects while other sciences still are offered in few schools or have few students.

Accompanying this article is a table which gives, for each state, the total numbers of schools and enrolments, and the registrations in each of the four sciences in both 1928 and 1934. Earlier studies of a comparable nature have been made and published by the U. S. Office of Education every five years from 1890 to 1915, and in 1922 and 1928.

Nobel Prize Awards

National Trends in Nobel Prize Awards. H. Hale; *Sci. Mo.* **45**, 412–4, Nov., 1937. When Alfred Bernhard Nobel, Russian chemist and manufacturer, provided in his will that the income from $8,000,000 be used to award prizes in five fields of endeavor "without any regard to nationality" he established a yardstick of national achievement. Nobel died in 1896, and annual awards have been made by designated groups of distinguished Europeans since 1901 in the five fields of physics, chemistry, physiology and medicine, literature, and peace. The total number of awards in all five fields through 1936 is 155, the number of nations represented being 19. The five countries receiving the largest number of awards through 1936 are: Germany, 37; England, 21.5; France, 19.5; United States, 17.5; Sweden, 10.5. The distribution of the *physics* awards through 1936 is: Germany, 10; England, 7; France, 4; United States, 3; Sweden, 2; Switzerland, 1; Holland, 3; Denmark, 1; Austria, 0.5; Italy, 0.5; India, 1.

Germany's preeminence is evident, for awards in the five fields to Germans have been between 20 and 28 percent of the total during the whole 34 years. Awards had been made to 12 nations before recognition came to the United States in 1906, when the peace award was made to Theodore Roosevelt. In 1911 the percentage for the United states was only 3.6, but since then it has increased, especially during the last eight years. Since the World War as many awards have gone to Americans as to Englishmen, only those to Germans being greater. During 1929–36 the distribution for the five countries previously mentioned is: United States, 9.5; Germany, 8.5; England, 7; France, 2; Sweden, 1.5.

Professor D. Wilson Crouse, 1872–1937

D. WILSON CROUSE, professor of physics in Midland College, was born near Zanesfield, Ohio, on August 2, 1872. He completed his work for the bachelor's degree at Wittenberg College in 1900 and later received the master's degree from Wittenberg and from the University of Michigan. He had finished also his work for the doctorate except for presenting a thesis. After holding various school and college positions, Professor Crouse went to Midland College in 1906 as professor of natural sciences. In 1914 he was made professor of physical sciences and, when Midland was moved to Fremont, from Atchison, Kansas, in 1919, became professor of physics, a position which he held until his death on September 5, 1937. He also served Midland in various other capacities, most important of which were those of registrar from 1910 to 1927, vice president from 1931 to 1933, and credit adviser from 1927 until his death.

Professor Crouse was a member of the American Association of Physics Teachers and of the American Association for the Advancement of Science. He was a member of the Council of the A.A.A.S. at the time of his death, was a past-president of the Nebraska Academy of Science, and was the author of a laboratory manual for physics.

It is certain that a serious attention to the sciences and liberal arts softens and humanizes the temper, and cherishes those fine emotions of which true virtue and honor consist. It rarely, very rarely happens that a man of taste and learning is not, at least, an honest man, whatever frailties may attend him.—David Hume.